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THE FELLOWS MACHINE AND CUTTER FOR GENERATING GEAR-TEETH.

[*Being the Report of the Franklin Institute, through its Committee on Science and the Arts, investigating the invention of E. R. Fellows. Sub-Committee.—Wilfred Lewis, Tinius Olsen, Arthur M. Greene, Jr.*]

HALL OF THE FRANKLIN INSTITUTE,
[No. 2025.] PHILADELPHIA, March 1, 1899.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of Fellows' Machine and Cutter for Generating Gear Teeth, reports as follows:

The Fellows gear-shaper is a machine designed to generate a complete set of interchangeable gears from a single cutter, which is in form similar to one of the gears produced. It consists essentially of a frame or housing adapted to carry the gear blank and the cutter slide in proper relation to each other and connecting mechanism whereby the gear blank and the cutter are caused to roll together on

their pitch lines while the latter reciprocates like a shaping tool and cuts away the material presented to it in the wheel blank.

The gear-shaping machine is the subject of U. S. patent, No. 579,708, dated March 30, 1897, and the cutter and cutter-head thereof are covered by another patent of even date, No. 579,570. As shown and described in the former patent, the gear-shaper differs somewhat in its details of construction from the latest designs, an example of which was examined by the chairman of this sub-committee at the works of W. D. Forbes & Co., Hoboken, N. J., and in its present approved form an idea of the machine can be had from the illustrations shown in the *American Machinist* for December 7, 1897, and in the *Iron Age* for June 2, 1898, as well as from photographs accompanying the inventor's application and engravings published herewith.

The most novel feature of the machine, and that upon which its successful operation chiefly depends, is the cutter. This is essentially one of the gears in the set to be cut, modified as required to adapt it for use as a cutter. These modifications include a certain lengthening of the addendum to provide root clearance in the wheel cut, top rake on the cutter faces and clearance angles on the cutter sides to facilitate the cutting process. Provision is also made for the continued use of the cutter by grinding, after it has become dull in service. It will readily be seen that a cutter thus formed and mounted can be made to produce tooth forms in a wheel blank rolled against it, which will engage the cutter pinion in proper rolling contact, and it may follow as a consequence that wheels which roll properly with the same pinion on the same pitch line will roll properly together. This general proposition must, however, be guarded by two considerations; first, the form of the cutting tooth must be a true odontic, capable of generating a rack with equal congruent branches, and, further, the shaping edge of the cutter must be sufficiently extended to form the actual working face on all the engaging wheels. The principle that one tooth form can be described from another in a mating wheel has been known for half a century at least,

and the process is clearly described in Willis' "Principles of Mechanism," edition of 1850; but it was not until November 16, 1881, that a practical suggestion of the application of this principle in a machine for cutting gear teeth was made. At that time Mr. Hugo Bilgram read a paper before the Franklin Institute entitled "A New Odontograph," in which he suggested for the first time the employment of a rack cutter in a shaping machine for the production of gear teeth in a wheel blank rolled against it.

Previous to this, in 1856, a somewhat similar idea had been advanced in England for the use of a hob in cutting spur gears, but the practical difficulties encountered must have discouraged the pioneers in this field, for, since then, the original idea of a machine for this purpose has been pursued with so little diligence as to have been repeatedly re-invented and re-patented in this country and abroad, and the process still seems to languish without evidence of commercial success. The hob generator differs, however, from the suggestion of Mr. Bilgram, in requiring the use of an expensive cutter with many teeth difficult to maintain in proper shape and working condition, whereas the Bilgram machine contemplated a cutter of the simplest form most easily reproduced. Notwithstanding the fact that the possibility of a practical machine for generating spur gears by means of a rack cutter was thus set forth about eighteen years ago, very little progress in this field appears to have been made since 1885, when a machine of this character was developed and patented by Ambrose Swasey. Here the cutters and gear blank moved together tangentially, and the effect of a continuous rack was obtained by shifting the cutters back to their original position during their return movement. A continuous cutting action was thus obtained, but at some disadvantage in effective construction. Mr. Fellows has extended the idea of a rack cutter to embrace a pinion cutter, thereby permitting a continuous rolling action between the cutter and the gear blank, and the use of the same cutting teeth repeatedly in the production of a gear wheel. The pinion cutter is also applicable to internal gears which are obviously beyond the scope of a rack cut-

ter, and, as an original conception of a practical machine having a large range of usefulness, the Fellows gear-shaper is clearly an invention of unusual promise; but a closer study of the cutter and the machine in general should be made before a definite conclusion upon their merits and possible defects can be reached.

The cutters presented for consideration are of two kinds, one of which appears in patent No. 579,708, as used on the machine there described in a position inclined to the face of the blank for giving the necessary clearance. As the cutter bar advances upon the wheel blank the slide upon which it is carried is made to recede a proportionate amount so that the resultant movement of the cutting edges is vertical. Here the cutting teeth are formed upon a cylinder, and may be ground after hardening to perfect involute form, and the cutting edges may be renewed, as required, by grinding their end faces without causing any change in their form or pitch diameter. The inclination of the cutter is so slight that its effect in distorting the effective shape of the cutting edges may be neglected as inappreciable, and in this form it is believed that the theoretical requirements for a renewable cutter have been practically solved. But the compound movement of the slide and saddle introduces more wearing surfaces to be maintained and more sliding joints to contribute their share of imperfection in the work, and in actual practice this feature has been abandoned in favor of a cutter with ground clearances mounted in a saddle which remains fixed after the proper depth of cut has been attained.

This cutter is described in patent No. 579,570, as "formed as a bevel-gear," the necessary side clearance being obtained by backing off about half a degree on a side. This method of obtaining clearance in the cutter implies a change of shape as the cutting edge is renewed by grinding, and this could not be accepted as meeting theoretical or perhaps even practical requirements, but from the method of grinding the cutters to proper shape, as illustrated and described in the *American Machinist*, referred to, it is believed that the sides of the teeth in the cutter

are really right and left hand spirals of very long pitch, and that they cannot properly be considered as resembling bevel-gear teeth at all. This view of the matter leaves nothing but clearances to be affected by sharpening, and grinding on the face of the cutter can evidently proceed without detriment to the wheels produced until the clearances originally provided are exhausted. The cutter, as thus made, cannot maintain, after grinding, absolutely the same tooth profiles as the cutter first mentioned and described in the patent, but the tooth forms are nevertheless just as true, and differ only in the non-essential element of clearance. Having thus provided clearance on the cutter teeth, it became possible to dispense with the compound slide originally intended for the same purpose, and a decided improvement in the actuating mechanism was thus brought about, giving the whole machine the appearance of greater simplicity, durability and effectiveness in its operation. This cutter combines the advantages of being ground easily and truly to perfect form, after hardening, by special mechanism used in its manufacture, and of afterwards being sharpened by grinding on its face only in an ordinary lathe, and these practical considerations cannot fail to win for it general favor, which it well deserves.

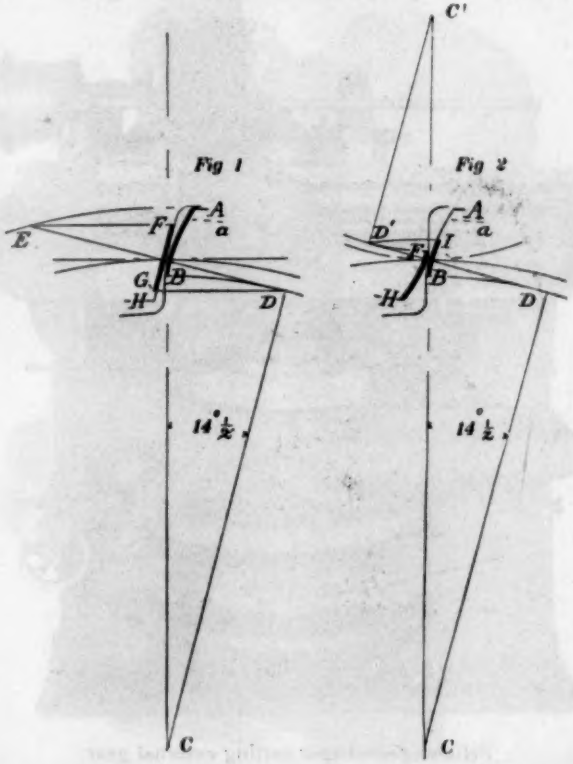
But, before stamping it with the seal of unqualified approval, some examination should be made with reference to its scope and limitations. The principles used in its construction may certainly be applied to an involute cutter having any number of teeth and any degree of obliquity, but attention should first be directed to the cutters actually made and put upon the market. These have twenty-four teeth and they are understood to be made for the production of involute gears in accordance with the Brown and Sharpe standard, $14\frac{1}{2}°$ obliquity. Here the addendum is ·3183 pitch, and the question arises whether this cutter of twenty-four teeth and $14\frac{1}{2}°$ obliquity will produce in the Fellows gear-shaper a perfect system of interchangeable gears from a twelve-toothed pinion to a rack; or, only a set of gears approximately correct, which may be run together without practical difficulty. It might at first be supposed that a

cutter generated from a rack by grinding would reproduce the same rack as a rolling cutter, but this does not necessarily follow, as will appear by reference to *Fig. 1*. Here the involute face of the cutter is shown by a heavy curved line *B A*, from the base circle *B D* to the addendum circle *A E*. That portion of the face between the base and root circles may be a straight line terminating in a fillet, or it may be undercut by the corner of the grinding wheel, depending upon how far the rolling of the cutter is continued while grinding; but it does not constitute a part of the true cutting edge of the cutter, and can only be regarded as an undeveloped or clearance edge on the cutter. The involute edge of the cutter acts along the line of action, *D E*, and generates within this line, the face, *G F*, on the rack. Between *F* and the root line there will be a clearance curve, and between *G* and *H* the point of the rack tooth will be more or less rounded. If the undeveloped edge of the cutter be left radial, the end of the rack tooth *G H* will be cycloidal in form, but if this edge be undercut, an important part of the face, *B A*, near the base circle, will be cut away, reducing the length of the true path of contact. It is not, therefore, possible to reproduce a perfect rack by means of the cutter in question, although it can be itself produced by a rack with equal congruent branches, but it is not denied that the differences pointed out cannot easily be observed in practice. As the number of teeth in the wheel cut is reduced, the rounded end, *G H*, grows shorter and finally disappears in wheels of thirty-five teeth and under. But another difficulty soon begins to appear in cutting pinions, and this will be understood by reference to *Fig. 2*. The end of the cutter, *I A*, which, on wheels of thirty-two teeth and over, forms part of the working face, now becomes engaged in cutting clearance below the base circle, and in the case of a twelve-toothed pinion, as shown in *Fig. 2*, the path of contact and the true working faces are very much reduced. The end *A* of the cutter also cuts away part of the face *F H* previously formed near the pitch line, and still further reduces the path of contact.

The larger the number of teeth in the cutter, the greater

will be the clearance swept out by the point *A*, and some interference might therefore be anticipated between pinions and large gears; but this danger of insufficient clearance is avoided almost perfectly by the extra addendum on the cutter, which provides root clearance at the same time.

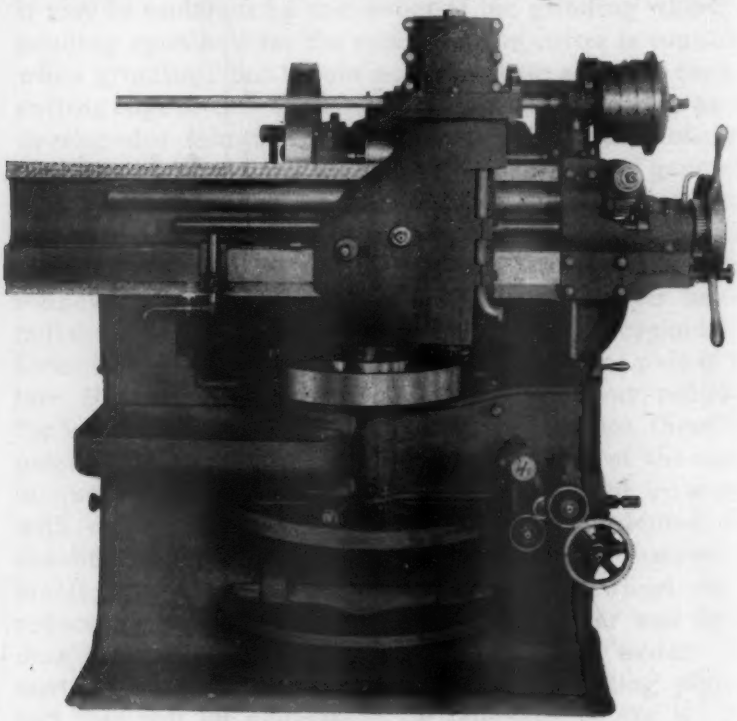
The commercial cutter submitted for examination thus appears to have some slight theoretical defects, but these



defects are inherent in the system to which the adaptation of the cutter is made, and not chargeable directly against the cutter itself, which will undoubtedly cut the teeth, for which it is intended, far better than they can possibly be cut by any set of equidistant cutters in the ordinary way.

The obliquity of the system is clearly at fault, and the

cutter adapts itself as well as possible to the difficulties presented, but as the obliquity is somewhat increased, the defects here noticed rapidly disappear, and the scope of the Fellows gear-shaper as a tool for the perfect formation of interchangeable gears becomes rapidly enlarged. The capabilities of the machine are broad enough to overcome all difficulties, and although cutters can easily be made of any desired obliquity, it has been thought advisable to

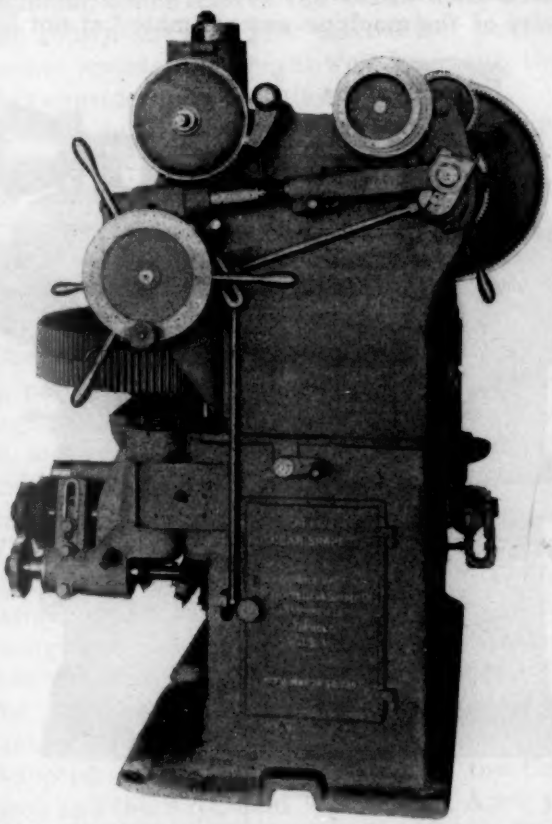


Fellows gear-shaper cutting external gear.

examine critically the cutters now on the market, and ascertain, if possible, the approach to perfection actually obtained in their use.

In the design of the machine throughout great ingenuity has been displayed and close attention has evidently been paid to every detail of construction, reflecting great credit upon the inventor. The cutter is perfectly made

to act on its rising stroke, pressing the blank against a stop on the head itself, thus minimizing the spring in the framework. On the return stroke the wheel blank is drawn away from the cutter to give the necessary clearance, and upon the completion of a wheel the feed is automatically disengaged and a bell sounded to notify the

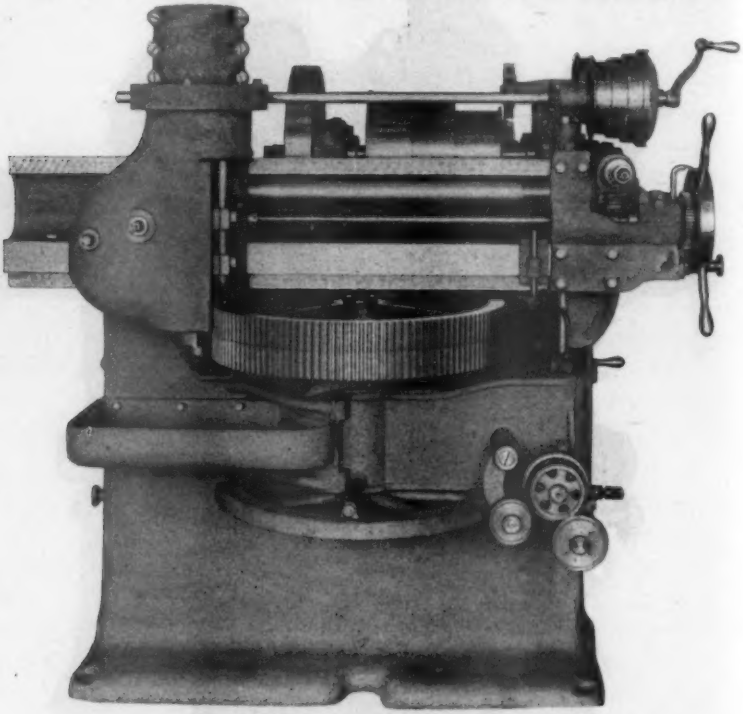


Fellows gear-shaper showing feed motion.

operator, who then removes the finished wheel and places another in position. When properly adjusted, the cutter feeds in automatically to the required depth, where it stops, and the wheel blank and cutter then begin to rotate together.

Although the driving mechanism was not particularly

powerful on the machine inspected and the feeds used seemed rather light, yet results were said to be produced with surprising rapidity, and to the perfect satisfaction of the owner of the machine. The witness, unfortunately, called at a time when the machine was not in operation, but from notes taken on the feeds and speeds in common use, the capacity of the machine was estimated at not less than



Front elevation of gear-shaper.

50 per cent. greater than common practice on gear-cutters in which a milling-cutter is used.

In view of the published articles on file with this application, it is not deemed necessary to encumber this report with further details of construction and operation. Suffice it to say that in design, general appearance and workmanship and in conveniences for adjustment and examination of parts, the Fellows gear-shaper is a very commendable

machine, on which there is little to be said by way of adverse criticism.

Possibly weak points will develop in time, for which the inventor will doubtless find proper remedies. At present, the speed of the machine seems to be limited by the cam mechanism, which moves the blank away from the cutter on the return stroke. This mechanism pounds heavily at moderate speeds, and might well be made the subject of further consideration on this account.

It may also be questioned whether a shaping tool can be pushed as hard as a milling cutter where rapid output is important on account of the well-known difficulty of preserving the edge of the work at the termination of a heavy cut in a shaping machine. On this account, a fine feed seems essential, and rapidity of production seems to be chiefly a matter of cutting speed.

The machine, as it stands, is, however, a well-developed tool, particularly applicable to the production of interchangeable gears, and the cutter used is more accurate in form, more easily renewed and covers a broader range of usefulness than the milling-cutters with which it competes.

Your committee believes that the machine and cutter for generating gear teeth, invented by E. R. Fellows, mark a distinct advance in the art of gear cutting, which should be recognized; and the Franklin Institute therefore recommends the award of the John Scott Legacy Premium and Medal to Edwin R. Fellows, of Springfield, Vt., for his "Machine and Cutter for Generating Gear Teeth."

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, April 5, 1899.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by
EDGAR MARBURG,
Chairman Committee on Science and the Arts.

THE LEVY ACID-BLAST METHOD OF ETCHING METAL PLATES.

[Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Louis E. Levy. Sub-Committee.—F. E. Ives, Chairman; Samuel Sartain, W. N. Jennings, Geo. H. Buchanan, F. E. Manning.]

HALL OF THE FRANKLIN INSTITUTE,

[No. 2061.] PHILADELPHIA, May 3, 1899.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of Levy's Acid-Blast Method of Etching Metal Plates, reports as follows:

Letters-patent for this invention were applied for under date of November 4, 1897, and granted on October 12, 1898. A second patent was applied for in September, 1898, and has since been granted.

Your committee examined the machine which was exhibited in operation and described by the inventor at the stated meeting of the Institute on February 15th, and which was found in practical operation at No. 628 Chestnut Street, Philadelphia. On this occasion the demonstration of the invention made at the meeting referred to was practically repeated. Besides the work actually in progress, a number of etchings were made especially for this investigation.

The invention consists in the application of an atomized spray of acid or other erodent, projected vertically upwards against the surface to be eroded by means of an air-blast, and in the combination of appliances for that purpose.

In the machine examined the blast was supplied through a receiving tank from an air pump at a pressure of from 5 to 8 pounds. The pump used was a Roots rotary air-compressor, and, in addition to this, the apparatus is composed of an etching case and a washing case. These two compartments adjoin, one in front of the other, and are fixed

over separate parts of an open shallow tank, which is divided by a partition. The compressed air passes from the air tank to the atomizers on the one hand and the washing appliance on the other, through pipes connected by two three-way cocks. These are so arranged that when one is open to let the air current pass to the aspirators, the other is open to let a supply of water pass to a water reservoir placed between them. The two cocks are joined by a connecting bar, which is actuated by a lever. A pipe connection from the first three-way cock carries the air current to a series of metal tubes placed below the bottom of that portion of the tank which contains the acid or other erodent to be used. A large number of atomizers project from these tubes, with their nozzles protruding above the surface of the liquid. The atomizers are constructed in the form of aspirators, consisting of a central tube open to the air current, which is surrounded by other tubes open to the liquid. When the air current is forced out through the central tube, it causes a vacuum in the surrounding tubes, which then become filled with the liquid to the point of the air opening, from which the passing blast carries it out in the form of a finely divided spray, in the manner and on the principle of atomizers generally. The atomized spray is driven by the blast against the surface to be etched, and then falls back into the receptacle below. The liquid is thus continuously used in the operation of the blast.

The atomizers are enclosed in a case, the sides of which are partly of glass, which makes the interior visible from the outside. On opposite sides of the interior of the case, at varying heights above the surface of the liquid, are fixed two pairs of narrow shelves, which serve to support open frames. These are movable, and are connected by a rod running through the back of the case to an arm which is actuated from the shaft of the air compressor. In each of these movable frames, and held in grooves, is another open frame, which slides out at the front of the etching box. This slide frame is rabbeted to receive a board, on the under side of which is fixed the plate to be etched. When this is slid into its place, the etching case is closed

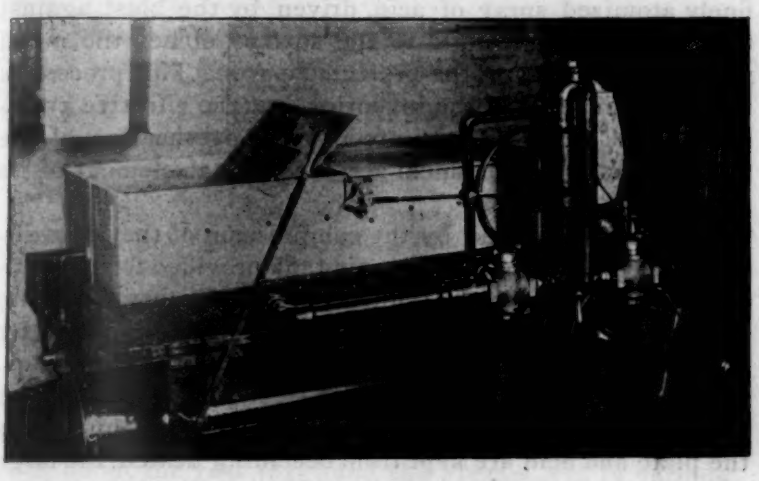
and the plate is then ready to receive the acid blast from the atomizers below it.

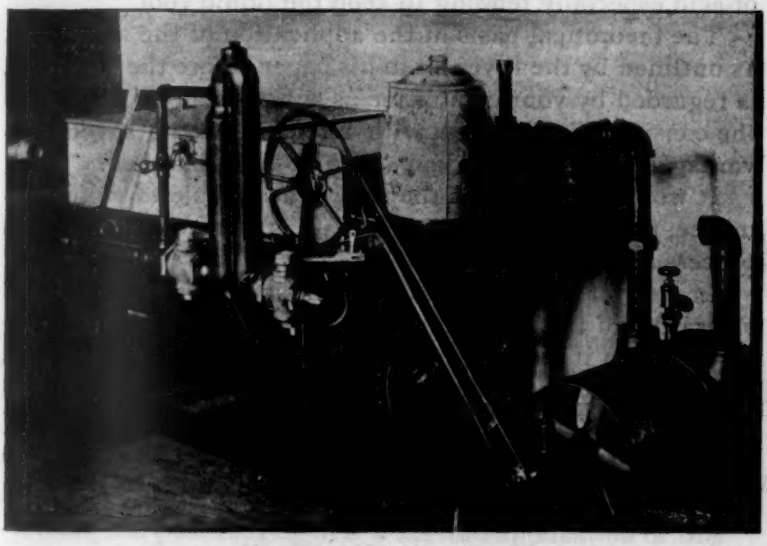
During the operation of the blast the frame with the carrier board is moved to and fro in a horizontal plane by the connecting rod and arm above referred to. The movement extends over a space equal to the distance between the aspirators, and serves to evenly distribute the action of the spray over the plate. At the same time it also gives a rocking motion to the drops of liquid which hang from the under surface of the plate, and this tends to deepen the erosion in the wider spaces of the etching and facilitates the fall of the drops.

When the etching process is to be interrupted or ended, the frame with the carrier board is slid out from the etching case to the washing compartment in front. At the bottom of this compartment are a number of perforated pipes connected by the second of the two three-way cocks to the water reservoir.

When the two cocks are turned by the lever and bar connecting them, the air current is directed to the top of the water reservoir and drives the water out through the perforated pipes at the bottom of the washing compartment, upward against the overlying plate. The water issues in a broad fountain jet and instantly washes the plate over its entire surface.

The erosion of the plate under the action of the blast of acid spray is very rapid, as was demonstrated at the Institute. In experiments made in the presence of your committee on zinc plates with nitric acid diluted to 10° Beaumé were etched in three minutes, without any undercutting, as deeply as the so-called "second etch" of the regular immersion method, which, including the four-way powdering, would take some twenty minutes at least. To erode the plate to this depth in an immersion bath with a single etch would require about ten minutes in an equally strong solution. It is, however, quite impracticable, with the bath, to carry the first etch so deep, or to force the erosion so rapidly, as the lines would be eaten away by the underetching, and the plate would become so heated by the decomposition of the





THE LEVY ACID BLAST.

The above two plates were made on hard zinc in a single etch of one and one-half minutes.

metal that the resistant would be apt to give way. The finely atomized spray of acid, driven by the blast against the plate at a right angle to the surface, etches the metal without undercutting the protected parts. This process is the main principle of the invention, but the effective avoidance of the difficulty presented by the overheating of the plate under strong chemical action is a vital element of its successful application.

The heat developed by the compression of the air is dissipated by radiation from the air tank provided for this purpose, and from the pipes leading to the aspirators, which are submerged in the outer tank containing the wash water overflow; and, in expanding when it emerges into the etching case, it absorbs an amount of heat fully equal to that evolved in the decomposition of the metal. By this means the plate and acid are kept from becoming heated, the large evaporating surface presented by the finely-divided particles of acid especially tending to keep the liquid cool.

The theoretical basis of the application of the acid blast, as outlined by the inventor in his paper before the Institute, is regarded by your committee as substantially correct, and the considerations stated, with reference to the several advantages of the process, appear to be fully justified.

It would appear, from the records accessible to your committee, that the Levy Etching Blast is a novel and original process and appliance.

In view of the importance of this invention, and in consideration of the originality of the idea and of the ingenuity displayed in its application, the Franklin Institute awards the Elliott Cresson Medal to the inventor, Louis Edward Levy, for his "Acid-Blast Method of Etching Metal Plates."

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, January 3, 1900.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by
EDGAR MARBURG,
Chairman Committee on Science and the Arts.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, June 20, 1900.

PRISMATIC LIGHTING FOR THE ILLUMINATION OF DARK INTERIORS.

By Dr. Wm. H. Greene,
Member of the Institute.

The practical application of the refractive property of the lens or prism to change the direction of light rays passing through it, for the purpose of artificial illumination, originated with the French physicist, Fresnel, who first suggested its use in lighthouses, for the protection of maritime coasts, about the year 1815; and the Fresnel lens in various modifications is to-day solely used for this purpose.

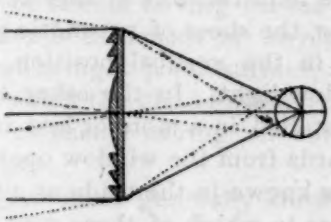


Fig. 1.

The Fresnel lens is designed for projecting a powerful beam of parallel light upon objects to be illuminated at a distance. The principle of this device is seen in *Fig. 1*, which shows a central plano-convex lens surrounded by a series of rings or segments of lenses or prisms, to which successively diminishing curvatures or angles are given in order to give them a common focus.

Within the past four or five years the application of this principle has been made, and with decided success, to the illumination of dark interior spaces, where the amount of light naturally entering therein is insufficient for satisfactory illumination, and artificial lighting must occasionally or constantly be resorted to.

The requirements of public buildings and modern office buildings, in this respect, have been most urgent, and the various devices known generally by the name of "prismatic lights" have been extensively used for the purpose and have proved so useful that in one or another form they have come to be regarded by architects and builders, not to speak of a great number of householders, as indispensable.

It is the purpose of this communication to give a brief review of the art of prismatic lighting, which, at the present time, is passing through the active stages of the course of evolution, to which all the arts are subject, in determining the survival of the fittest.

Omitting, for the present, consideration of the vault light for basements and cellars, where but one form of prism, namely, an approximately right-angled prism depending on total reflection for its utility, is admissible, there are two general methods in vogue of installing prismatic lights to meet the requirements of service.

In one of these, the sheet of prismatic glass is placed in a window-frame in the vertical position, thus taking the place of the window light. In the other, the sheet of prismatic glass is installed in a more or less inclined position, projecting outwards from the window opening. This form of construction is known in the trade as a "canopy."

The question as to which of these two forms of installation will give the best results is determined by the extent of the sky opening upon which dependence must be placed for light.

Where this is of considerable area, as for example where the windows face a wide street, the prismatic glass set into the window-frames in the vertical position will give satisfactory results.

Where the windows receive their light from a restricted area, as for example in court-yards, or the side-yards of dwelling houses, and, generally, in the many situations where high walls rising in close proximity cut off the free access of light from above, the projecting, canopy, form of prismatic glass is preferable.

Speaking in a general way, the change from the vertical

to the canopy form of installation will be indicated when the incident angle of the light falling on the window opening averages 60° from the horizontal plane.

The popularity achieved by the use of light-projecting devices of this general nature has called into existence a great number of patented inventions, some claiming special forms of prism construction (in combination, in certain cases, with a prismatic or lenticular formation on the reverse side of the glass), and of a far greater number of design patents and methods of glazing, and other matters of minor detail.

For the purpose of this communication, these minor devices may be left out of consideration, and the several generic forms of prism construction only will be given attention.

These may be divided into two general classes:

(1) Those in which the glass forming the light-projecting device consists of sheets having on one surface a series of prisms or segments of lenses of any desired angle, the back of the sheet being a plane surface, and

(2) Those in which the glass forming the light-projecting device consists of sheets having on both surfaces a series of prisms or lenses.

The prism glass most generally known and used is that of the first-named class.

The action of a section of prism glass of this construction is shown in *Fig. 2*, in elevation and plan. It is obvious that the general refracting effect of the prismatic surface in this and in the other forms of prism glass will be substantially the same, whether the refractive surfaces of the structure be straight (*i. e.*, prismatic), or more or less curved (*i. e.*, lenticular), irrespective of the angles of the prism sections or of the curvature of the lens segments. It is important, however, that these angles (or curves) be carefully considered, since upon the correct appreciation of this element the light-projecting efficiency of the structure largely depends. Improper angles (or curvatures) may greatly diminish the efficiency of the device, by the dispersion and loss of light, caused by total reflections in the interior of the glass.

There is general misapprehension regarding the proper action of light-projecting glass, which needs a word of reference. It is assumed by many that the prismatic glass should be so constructed that all the exterior light transmitted from the interior boundary of the prismatic window, or canopy, should be directed in lines substantially parallel to the boundary walls, floor and ceiling of the apartment, and that the more nearly this condition is realized, the closer will be the approach to the theoretically-perfect mode of operation. Some of the manufacturers of prismatic glass endeavor to realize this condition by varying the angles of the prisms uniformly from the center to the edges of the sheets, on the principle of the Fresnel lens.

A little consideration of what is intended to be realized by prism lighting of interiors will suffice to show that this view is an erroneous one and liable to result, in practice, in a much inferior interior illumination than can be otherwise obtained.

This criticism will be understood by stating the general proposition, that the objects of prismatic lighting are, first, to direct as much extraneous light into the interior as possible; and, second, to direct it in such manner as to derive the largest possible benefit therefrom.

In considering the relative merits of parallel and divergent light transmission by prismatic glass, it should be said that practically as much extraneous light can be directed into the interior space to be illuminated by the one as by the other arrangement of prisms or lenses. But, when we come to consider the second portion of the proposition, it can easily be shown that the system of transmitting the light in parallel lines cannot possibly be as effective as the method of divergent transmission, and more especially, divergent transmission in both vertical and horizontal planes, and for the following reason.

It is well known that the best effects in interior illumination are realized when uniform diffusion throughout the apartment is obtained. This effect can be secured most effectively only when all shadows are obliterated by calling into requisition the action of the entering light reflected

from all parts of the side walls, floor and ceiling of the apartment.

By the method of directing the transmitted light in parallel lines, the ill-effects of shadows cast by opaque objects in the path of the entering light will be realized in an extreme degree, as there will be no ameliorating influence to counteract and neutralize the shadows by reflection from the bounding walls and floor of the apartment; and an inspection of the condition of an apartment thus treated will disclose this objection at once.

By the method of divergent transmission, while quite as

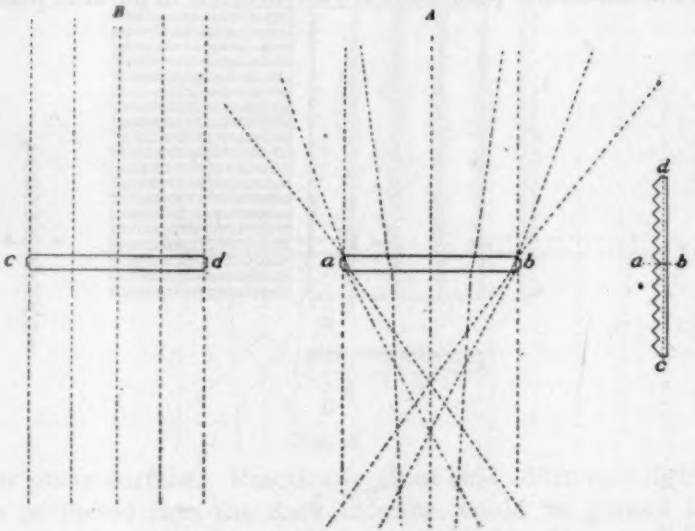


FIG. 2.

much or more extraneous light is thrown into the apartment, as by the other method, its distribution is decidedly more advantageous, from the fact that the repeated reflections from the bounding surfaces of the apartment cause the practical obliteration of all shadows and a practically uniform diffusion of the light to all parts of the interior.

Returning now to the descriptive portion of the subject, the *modus operandi* of the simplest form of a light-projecting prismatic window is shown in the plan views in *Fig. 2*, *A* and *B*, in which the light from an exterior source falling

upon the plane, outward surface of the glass is refracted at the boundary of the interior prismatic surfaces and projected into the room to be illuminated.

Fig. 2 A, which is a plan view of this construction taken on the line *a b*, exhibits the effect of the light distribution in the vertical plane from the effect of refraction from the terminal portions of the prism, where the influence of the more oblique rays is not counteracted by a modification of the angles of the prism from the center line to the upper and lower edges of the glass. *Fig. 2 B* is a plan on line *c d*, showing that the light rays are not distributed divergently in the horizontal plane, but are all directed in parallel planes.

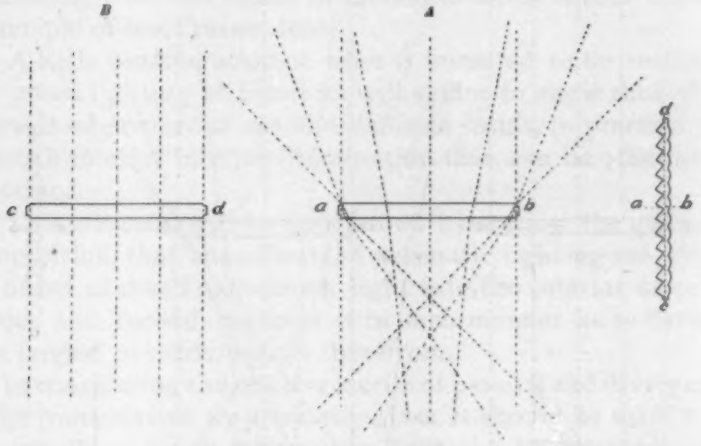


FIG. 3.

Figs. 3 and *4* represent the action of prismatic glass of the second class, *i. e.*, in which both surfaces are prismatic or lenticular.

Fig. 3 shows a form of light-projecting glass that has lately come into use, and for which certain advantages are claimed over the construction previously described. The sheets in this form of prism glass have one surface furnished with prisms—commonly placed towards the room to be lighted—and the other surface formed of a series of lenses of small curvature, distributed in panel form, *parallel* to the direction of the prisms. This construction, as well

as that shown in *Fig. 2*, manifestly exaggerates in the vertical plane the divergent distribution of the transmitted light, and consequently operates, so far as it goes, in the correct manner, utilizing the reflecting action of ceiling and floor in diffusing the light.

The construction shown in *Fig. 3* possesses one obvious advantage over the several modifications of class 1, namely, that the lenticular form of exterior surface arrests and directs into the dark interior to be lighted a certain amount of the exterior light, which, with the plane exterior surface of class 1, would be lost by total reflection from the ex-

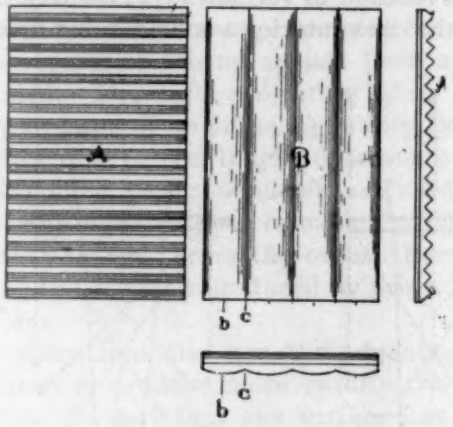


FIG. 4.

terior plane surface. Practically all of this additional light thus projected into the dark interior would be gained if the angle of the prism and the curvature of the lens panels were correctly adapted to the length of the apartment to be lighted.

The latest modification of class 2 remains yet to be considered.

In this, the interior prismatic surface of the glass is the same as that just described, but the exterior lenticular panels are arranged not parallel, but *transversely*, to the direction of the prisms. The details of this form of construction are shown in *Fig. 4*, *A* and *B*, while the *modus operandi* is best observed in *Fig. 5*, *A* and *B*.

The radical difference in the operation of this form of light-projecting glass and that of both forms previously described resides in the fact that the light distribution in this form is exaggerated in the lateral as well as in the vertical plane. This feature is illustrated in *Fig. 5 B*, in which *B* is supposed to be a section of the prismatic glass taken on the line *c d*, from an inspection of which it will be manifest that the vertical arrangement of the exterior lenticular panels will serve a similar purpose in this construction in relation to the light falling sidewise on the exterior surface of the glass as the lenticular panels in the previous case serve in relation to vertical rays; namely, to arrest and refract into the dark interior a considerable amount of light

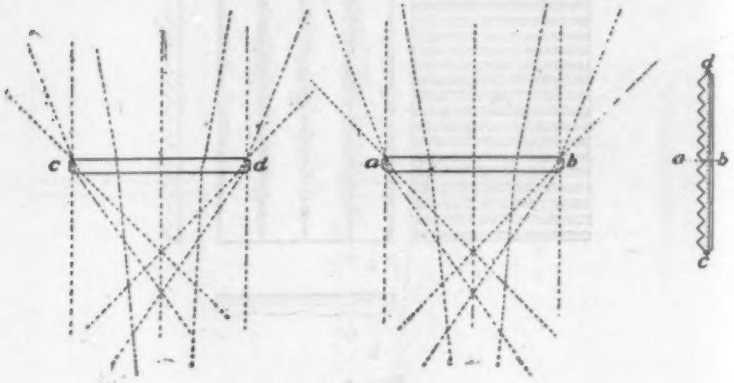


FIG. 5.

in the horizontal plane which would otherwise be lost for useful purposes. All of the light thus collected and introduced into the dark interior by the lateral collecting action of this device is so much clear gain over the devices previously described.

Further consideration will show, also, that if the interior surface of the glass be provided with prisms of uniform angle, determined in each case by the length of the apartment to be illuminated, this form of construction will secure the same advantage in respect of the vertical diffusion of the entering light as will be obtained from the lenticular prismatic construction previously described.

On theoretical grounds, therefore, the last-described

modification of light-projecting glass, belonging to class 2, should give the best results if intelligently installed. Comparative practical tests also bear out this conclusion.

An additional and important advantage possessed by prism glass of the last-named construction (namely, a prism plate constructed with prisms on one side and prisms or lens panels arranged transversely on the reverse side) remains to be noticed.

Since all illumination by means of prism glass is thrown from a comparatively low point, namely, through windows, while all other artificial illumination is directed from a point above, the shadows produced by the prisms on objects in a room constitute a disadvantage common to most systems of lighting by means of prisms, as has been noticed in what has preceded. The light-projecting glass last described, however, by reason of its diffusing quality, both in the horizontal and vertical planes, largely overcomes this objection. Where two such prism windows are used for the same apartment, the light thrown from one window completely overlaps that thrown from the other, thereby practically obliterating the shadows produced by prism lights of other constructions.

This construction also has the advantage of enabling manufacturers to produce more readily the larger sizes of prisms, from the fact that one surface has projections at right angles to projections on the reverse side, giving a bridge effect, thus adding to the strength of the plate. For this reason, likewise, it is not essential to have the thickness of the body of the glass as great as with other forms; and, inasmuch as there is a larger loss of light through absorption in passing through a thick than a thin medium, the loss of light from this cause may be much reduced.

Finally, it may be said that all the various forms of light-projecting prismatic glass accomplish, measurably, their intended purpose of considerably increasing the illumination of dark interiors over what would occur without artificial aid. In the selection of the kind of light-projecting glass and the manner of its installation, the user should be guided by the personal observation of the effects produced, rather than by the claims of rival manufacturers.

Stated Meeting, April 25, 1899.

ELECTROMAGNETIC MECHANISM, WITH SPECIAL REFERENCE TO TELEGRAPHIC WORK.

BY R. A. FESSENDEN.

(*Concluded from p. 80.*)

This means that all such devices as tapering cores, or plungers in unarmored solenoids, should not be used, and must be supplanted by types like the following, *Fig. 6, a, b*

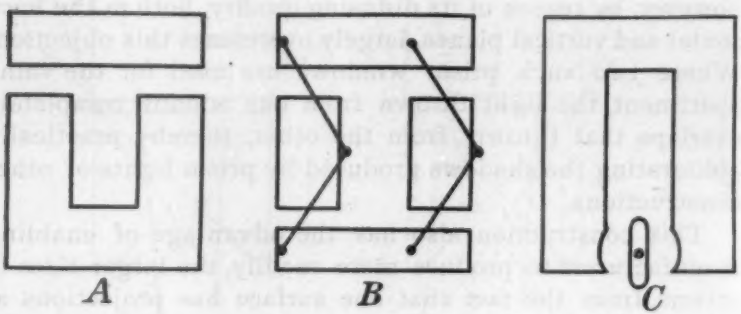


FIG. 6.

and *c*. Of these, however, there is only one which is worth considering, *i. e.*, *c*, the others all being markedly inferior to it in all respects.

In designing this, we may be guided by either one of two considerations:

(1) Efficiency.

(2) Energy for given weight of moving part for given angular motion, *i. e.*, torque per gram.

Taking, first, efficiency, we see at once that by Rule I, the flux through the armature before it begins to move should be small compared with that when the armature has ended its motion. Suppose we wish to get 80 per cent. of the

theoretical efficiency, *i. e.*, 40 per cent. of the total energy spent, then since the energy available is

$$\frac{1}{2} L I^2$$

and L I equals the linkages $P n$ and n is constant, then, P should be only 20 per cent. in the first position of the armature of what it is in the last position.

But when we are working the iron economically, practi-

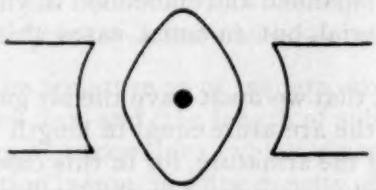


FIG. 7*a*.

cally all the reluctance is in the air gap. How to calculate this most efficient point will be given later; at present suppose it to be where $\mu = 2{,}000$ and that the air gap is but 1 millimeter in length, the length of the magnetic circuit being 10 centimeters. Then we see that the reluctance in the iron is only one-thirtieth of that in the air, so that practically we can neglect the iron, and the flux will

FIG. 7*b*.

be inversely proportional to the length of the air gap.

This being the case, we see that the air gap must be five times as long before the armature has started as when it has come to rest. We can arrange this in several ways, for instance, as shown in *Fig. 7a*.

But there is one objection to this form, and that is that the flux is apt to have a higher density just as the armature reaches the pole tips, and this means hysteresis and uneven

pull. Moreover, we should have as little inertia in the moving part as possible, for that means, as pointed out previously, more loss. Now, of all forms the cylinder is that which has least moment of inertia, and fortunately it is that which can be made to give the best distribution of lines. Construct a cylinder, as shown in *Fig. 7b*, of laminated sheet iron, the laminations being horizontal and separated by sheets of non-magnetic material equal in thickness to the sheets of iron. Still better would be the use of layers of wire, japanned and embedded in vulcanized rubber or similar material, but in most cases this would be too expensive.

It is evident that we must have the air gap between each pole piece and the armature equal in length to one-eighth of the diameter of the armature, for in this case the reluctance will be five times as much when the laminæ are perpendicular to the lines of magnetic flux as when they are parallel.

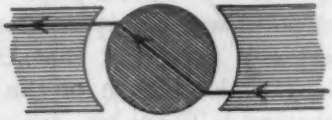


FIG. 8.

This is only approximate, as when the laminæ are parallel the effective area of the air gap is only approximately double the cross-section of the laminæ. If, of course, there were no spreading of lines from the edges of the laminæ, the area would be smaller, but the spreading gives practically the full area.*

It is evident that the change of flux will be gradual, as when the armature has turned through 45° the lines have to pass diagonally across the laminæ and not as shown in *Fig. 8*.

Supposing, then, that we wish to design a mechanism to do a given amount of work, say 1 joule, and we have the voltage given as 10 volts. The efficiency being 40 per cent., then we need $\frac{100}{40} = 2{\cdot}5$ joules.

* I have since found that the approximation is very close indeed.

If the resistance of the circuit be taken at 1 ohm, and I as 10, we get

$$\frac{1}{2} L I^2 = L \times 50 = 2{\cdot}5 \text{ or } L = {\cdot}05$$

which, since we have taken I in ampères, and work in joules, will be in henrys, and equals

$\cdot 05 \times 10^9 = 5 \times 10^7$ linkages per unit current, or total linkages $L I$, equal

$$5 \times 10^8 = \text{lines} \times \text{turns}.$$

If we take the armature as of square cross-section, perpendicular to the flux, and (the length of side being x) wish to work the iron at 10,000 lines (which, since only one-half of the cross-section is iron, is a flux density of 5,000), we get, since the length of the air gaps is one-quarter the diameter of the armature,

$$5{,}000 \times x^2 = P$$

$$\frac{\cdot 4 \pi n I}{\frac{1}{4} x \div x^2} = \text{flux} = 5{,}000\ x^2 = \frac{5 \times 10^8}{n}$$

whence since $I = 10$

$n = 450$

$x = 4{\cdot}5$ approximately.

This is the best mechanism of this class which it is possible to make to do this work, for the following reasons:

(1) The moving part has the least amount of inertia possible.

(2) There is the greatest return, for energy expended, possible for mechanism of this class.

(3) It is the lightest for equal efficiency, and if this be lowered, can be altered so as to be lighter than any other mechanism of the same class to do the same work.

(4) It gives the least amount of material possible, if the flux is properly determined as by the methods given below. It has also other important advantages, the chief of which is this. In most mechanisms what is needed is a large force at first and practically none at the end. In the usual

methods, if the force be strong at first, it necessitates much waste of energy, as shown above (Rule I), and the pull is strongest at the end where it should be weakest (otherwise the armature goes on gathering up momentum, which is lost, unless it is desired to obtain a hammer blow, as in striking bells). But in the above type, by attaching a crank or cam to the axle so that the crank is in line with the arm to be moved, the slight force at first exerts the greatest leverage just when it is needed. Moreover, by suitably spacing the layers of iron and non-magnetic material in the armature and field, the pull may be made to follow any law desired. A convenient form is shown in *Fig. 9*, where *W* is

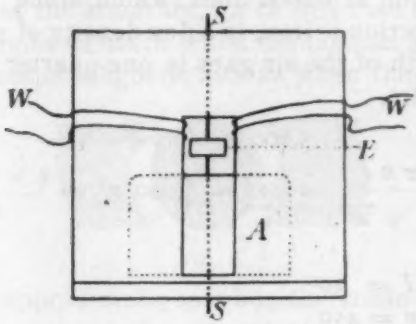


FIG. 9.

the wire, *A* the armature, *S* the shaft, and *E* an eccentric, which gives the pull.

Again, it is possible to obtain more energy out of it than

$$\frac{1}{2} L I^2$$

in the following way. Wrap around the field a short-circuited coil of very low resistance. On putting the current on, it will exert some detrimental effect, *i. e.*, waste some energy.* Before the armature has come to its final position, break the circuit. An induced current will

*As much energy must be wasted in $I^2 R$ losses in the short-circuited coil as is equal to the energy gained by the use of the short-circuited coil. Hence, this gain is in weight, not in efficiency.

be set up in the coil *D*, and this will tend to keep the flux constant. But the energy of the flux, which is practically all in the air gap, equals

$$\frac{\text{flux} \times \text{gilbertance}}{2}$$

The flux remains the same, but if the armature moves on the gilbertance will be less. Consequently the armature is forced on, and this energy [one-half flux × (original gilbertance — final gilbertance)] is gained as mechanical energy, and at the same time the sparking is very greatly reduced.

The field should be of laminated iron, and in the same plane as the shaft of the armature.

Suppose it be desired to increase the force with the same armature, at the expense of a slight loss in efficiency. We can do it very simply. Remembering that practically all the stored energy is in the air gap and that the energy we can utilize is numerically equal to this, suppose we wish to get double the energy, all we have to do is to double the length of the air gap. A little of this will be lost, as now the flux in the first position of the armature will be a larger fraction of that at the end than before, and this is where an additional loss of efficiency comes in, the initial L being say one-third of the final L.

But we need no greater voltage or current than before and no greater $I^2 R$ loss, as all we need to do is to use double the turns and wire of twice the diameter. This will necessitate lengthening the magnetic circuit, but that is no matter, as the reluctance there will still be negligible compared with that of the air gap.

We will now have double the work for the same motion, and in many cases this is appreciated more than a small gain in efficiency. It is sometimes thought that force is gained in such cases by increasing the induction, the increment varying as the square of *B*. This, as will be seen from what I have shown, is a mistake, the work done for given motion, and therefore the average force, varying directly as *B*, *i. e.*, in the case where the gilbertance is fixed in amount. For, if we halve the air gap,

and so double the flux, the energy per cubic centimeter in the air gap $B^2/8\pi\mu$, is quadrupled. But there is now only half the volume in the air gap, hence the total energy in the air gap is only doubled, and since, as we have seen, the available mechanical energy is equal in amount to that stored up in the air gap, by doubling our induction we have only doubled the mechanical energy. Of course, as we increase the flux, keeping the air gap constant in length and area, the average force does increase as B^2, but this is due to the fact that the gilbertance is being increased too, and it is much better to increase our force by simply lengthening the air gap, keeping the current and $I^2 R$ loss the same, than to do so by crowding the iron, which cannot be

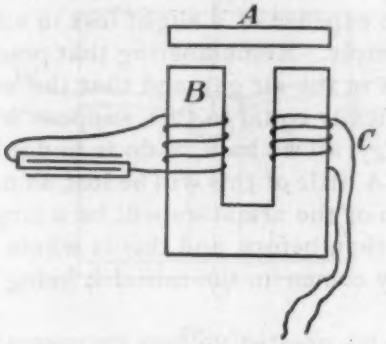


FIG. 10.

done in any case, *i. e.*, if working at 10,000, it cannot easily be pushed above 15,000, while it is a simple matter to increase an air gap from $\frac{1}{8}$ to $\frac{1}{4}$ inch, thus getting the effect of 20,000 weberivity.

The following devices may be of interest. In certain instruments the armature approaches closely to the fields, and is apt to remain there unless pulled back by a powerful spring, and energy is of course lost. A much weaker spring can be used with either of the following devices:

I. In *Fig. 10*, *A* is the armature, *C* the operating coil and *B* a coil of many turns, connected to a condenser. In breaking the circuit *C*, a voltage is set up in *B*, and the condenser is charged. If the circuit is properly tuned, the discharge

from the condenser will tend to demagnetize the circuit and make *A* let go. Useful for telegraphic instruments.

II. Use a part of the kinetic energy stored up in the armature to free the armature itself. Thus, attach a light arm, with a small weight on it and hinged to *A*, so that *A* stops before it does, whilst it goes on and, by its reaction on finally striking its stop, throws *A* back. This is not so good, however, and if a spring be properly adjusted, it is almost as efficient.

In the first-mentioned device, if a band of copper be placed about the armature it will help the throw-off, but is bad during the approach.

In all that has been written above, the time constant of the circuit has been neglected. The time constant, or the time taken by the current to rise to all but the $1/\epsilon$ th of its full value (ϵ, being the base of the natural logarithms) is, as is well known, for constant effective voltage applied, equal to L/R. If, therefore, we have, with a current of 3 ampères, 9 henrys linkage, the resistance of the circuit being 5 ohms, this time is

$$\frac{9}{3} \times \frac{1}{5} = \frac{3}{5} \text{ seconds}$$

and the apparatus cannot, of course, under these conditions make two movements per second, as at the end of three-fifths seconds the current has only reached 1/2·7 of its full value (in fact less, as this is the amount it would have reached if there had been no back voltage in the coil due to the movement of the armature). Just how much less can be found by taking the mechanical work done, velocity, etc., at every point in its path, which is quite a complicated thing. In most cases, however, the time constant need not be more than doubled to allow for this. In the next three-fifths seconds, or after six-fifths seconds from the start, there will be but

$$\frac{1}{\epsilon} \times \frac{1}{\epsilon} = \text{about } \frac{1}{7}$$

of the full value of the current lacking, which is close enough for such work. So that, with the above values for

L and R, the current would not reach its full value in less than $12/5 = 2{\cdot}4$ seconds, and consequently could not make more than about one stroke in three seconds.

To have a low time constant means that you must have a high resistance or low self-induction. But since the work we get is

$$\frac{1}{2} \mathrm{L}\, I^2,$$

if we take L as one-quarter of what it was at first, we must have twice the current. But $\mathrm{L}\, I^2$ is the power put into the coil, half of which,

$$\frac{1}{2} \mathrm{L}\, I^2,$$

we get as mechanical work and half of which is lost at the instant of sparking. Also $R\, I^2$ is proportional to the power wasted in heating the coil (proportional, because the current is not steady, but if we double I, and it varies in the same way, we get I^2 times the heating), so that our efficiency is

$$\frac{\frac{1}{2} \mathrm{L}\, I^2}{\mathrm{L}\, I^2 + c R I^2 t}$$

where t is the time the current is on, *i. e.*, the time of the movement of the armature. It is, therefore, apparent that all we have to do to keep the efficiency constant is to keep $R\, t$ a constant. If, therefore, we wish to make the mechanism work in one-quarter the time, add three times as much resistance to the circuit, and it will be just as efficient as before.

This seems at first glance foolish, for we must then have four times as much voltage as before, and the $I^2 R$ loss is four times as great as before, so one might think the efficiency must be lower. But the reason is that the given amount of mechanical work is done in one-quarter the time it previously was, so that though the $E\, I$ and $I^2 R$ power are four times as great as before, yet t is only one-quarter, so that $E\, I\, t$ and $I^2 R\, t$ are the same, and so the ratio work got out ÷ work put in is not altered.

Since I^2 enters into both numerator and denominator, it is evident that the efficiency is independent of the current. But if we double I, we can reduce L to one-quarter of what it was before and still get out the same work, and in this case, to keep the efficiency the same we must have $R I^2 t$ the same. But if I is doubled, then, since L/R is proportional to t, if we wish to have $\frac{1}{4}$ its original value, R must remain the same. Here, then, as before, we must increase the voltage, in this case, however, only to double of what it was before, the power $E I$ and the heating $I^2 R$ being quadrupled as before, but the efficiency being the same.

To get $L I^2$ the same, with $L\ 1/4$ and I twice their previous values, means that $L I$ is halved. This means that if we keep the turns the same we must quadruple the length of the air gap, or take a quarter of the cross-section of the iron, the latter, of course, being preferable, as it makes the armature only weigh $\frac{1}{8}$ as much as before, and its moment of inertia, if of the circular type, is but $\frac{1}{32}$ of the original figure.*

Thus it happens, fortunately for telegraphic work, that at the same time that we reduce the time of movement we reduce the moment of inertia, thereby giving a greater yield of mechanical work in the way needed. This also gives the least amount of hysteresis loss.

It is to be noted that this additional voltage can be got in some cases by means of a condenser, for instance, if an alternating current be used. Another advantage in working with somewhat large air gaps is this: Suppose the original air gap to be 1/25 inch. Owing to necessary mechanical imperfections, there will be a certain amount of

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*We could, of course, instead of keeping the turns the same, take half the number of turns and keep the air gap the same. If we choose to follow the rule that the impedance of the receiving instrument should equal the impedance of the line, then the problem becomes perfectly determinate. But this rule is not to be followed in most cases. For instance, in long-distance trunk lines it is best to use a high voltage, say 200 to 1,000 volts; in fact, to treat such lines, as I have put it elsewhere, as long distance transmission lines, and use most of the voltage up in the instrument and very little in the line. For cables the case is different in some ways. The whole question is somewhat complicated, and will be dealt with in another paper.

backlash. If this be 1 / 50 inch, we are only getting the benefit of a 1 / 50 inch air gap, while expending the energy of a 1 / 25 inch; *i. e.*, throwing away half of the energy, our total efficiency therefore being less than 25 per cent. With longer air gap, this loss is not so great; *i. e.*, with 1 / 10 inch, a backlash of 1 / 50 inch would only increase $L I^2$ 20 per cent., and our total efficiency would be 40 per cent.

Class III. In this class the magnetic field is constant, whether permanent or electro-magnet be used, and its efficiency may reach nearly to 100 per cent., and so is more than twice as efficient as mechanisms of Class II. Moreover, the total weight is sometimes lighter, as, with a given magnetic circuit, exciting winding, and armature, we see that, if the mechanical energy obtained by letting the armature move, in a mechanism of Class II, is

$$\frac{1}{2} P n I$$

then by narrowing the air gap 10 per cent. and putting the wire now no longer needed on the fields into the shape of an armature coil, it will be capable of doing mechanical work numerically equal to

$$2 P \times \frac{1}{10} n \times 10 I = 2 P n I,$$

or four times as much as before, with the same voltage, or, if we keep both current and voltage the same, and put half the turns on the armature and decrease the air gap to 1 / 2, then

$$2 \times P \times \frac{1}{2} n \times I,$$

or twice as much as before. The time constant may be made practically zero, for, if we saturate the magnetic circuit, the permeability will be extremely small.

Considering, however, the weights of the moving parts, in Class II the energy is practically all in the air gap and equal in amount to

$$\frac{B^2}{8\pi} \times \text{length of air gap} \times \text{cross-section of air gap.}$$

Taking the length of the air gaps as together equal to one-quarter the armature diameter, we have, x being diameter of armature,

$$\text{energy} = \frac{B^2}{8\pi} \times \frac{x^3}{4}$$

Total volume of armature is

$$\frac{\pi}{4} x^3$$

$\therefore$ energy per cubic centimeter of armature equals

$$\frac{B^2}{8\pi^2}$$

and the energy per gram weight of armature is independent of its size. Since only half the volume of the armature is iron, the energy per cubic centimeter of iron is

$$\frac{B^2}{4\pi^2}$$

In Class III, however, the force on the wire is

$$B_1 \times \text{length} \times \text{current}.$$

Taking the current density as 500 units (5,000 ampères) per square centimeter, and the coil as square in shape, then if the wire moves in an air gap of length x and width $\frac{1}{8} x$ (the maximum volume efficiency being evidently got when the wire is all outside the gap when it starts, and all outside when it ends its motion), we have,

$$\text{work} = B_1 \times 2x^2 \times \text{current}.$$

The volume of copper is

$$4x \times \frac{\text{current}}{500}$$

The work per cubic centimeter of copper is therefore

$$\frac{B_1 \cdot x^2 \cdot \text{current} \cdot 500}{2H \cdot \text{current}} = 250 B_1 x.$$

But B_1 is here twice B for Class II, and we get

$$500 B x.$$

If B is 10,000, we find (if we take the mean density of the iron sheets, plus the oxide and air spaces as one-half that of the copper), that the amount of mechanical energy given out by equal weights of moving parts are equal when

$$500\, B\, x = \frac{B^2}{4\,\pi^2}$$

or,

$$x = \frac{1}{20} \text{ centimeter.}$$

Thus, when the diameter of the armature in Class II and the diameter of the coil in Class III are each $\frac{1}{20}$ centimeter in diameter, they will give equal amounts of energy per gram of moving parts. The iron will have less moment of inertia, however, so that roughly we may say that, for a given output,

Above $\frac{1}{10}$ centimeter Class III is best.

Below $\frac{1}{10}$ centimeter Class II is best.*

This shows us why, with a given length of period, we can never obtain the same sensitiveness in a copper coil galvanometer as in an iron armature one.

I might mention the following device for preventing sparking in oscillatory magnetic mechanisms used with direct currents. I was called in to advise some men who had an electric reciprocating pump and who were having trouble with sparking. They were trying to get over it by shunting it round resistances, so as to make the current a sine curve. This, of course, was a very inefficient way. I suggested the device shown in *Fig. 11.*

$N\,S$ is a permanent of electro-magnetic circuit, and A and B coils mounted on a tube which can move horizontally, and surrounds an iron core. Make the current in A and

*It is, however, assumed here that the flux density in Class II is half that of Class III. For different ratios of B these diameters would be slightly different.

it will drive the tube to the right. Just before breaking *A*, short-circuit *B*. Then break *A*. A current will be set up in *B* and there will be practically no spark at *A*. This current in *B* will tend to drive the tube to the left, and will thus act as a sort of electric buffer, or as the equivalent to an air cushion or spring.

S. P. Thompson's method, "Electromagnet," p. 278, can also be used for this purpose, and is a very good one. It consists in using two windings which oppose each other, and producing a magnetic flux by opening one circuit, when there is, of course, no spark.

DESIGN FOR LEAST COST OF WIRE IRON AND LABOR.

The chief item is of course the last, unless American methods of manufacture be used, and this depends upon

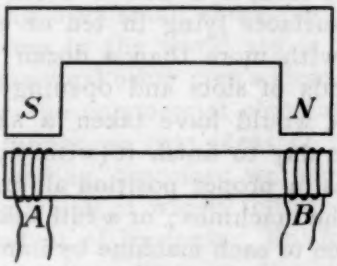

FIG. 11.

how many have to be made. It is a curious and instructive thing to notice how the methods which were put in use for the cheap manufacture of common things were finally extended under pressure of competition, necessitating more and more accurate work, till finally, greater accuracy is now reached in the manufacture of large parts of machinery than used to be reached by the old watchmakers. I remember visiting Maxim seven or eight years ago, when he was in the midst of his work on the flying machine, and on asking him how he liked England after the old place at Newark, I learned that England was a land "where every prospect pleases and only the machinist is vile." He could not get them to understand the meaning of the $\frac{1}{1000}$ of an inch,

and consequently when he would order material 2 inches in diameter it might be 2·01 or 1·99, a thing he did not appreciate after having had men who worked regularly to 0·0002 inch, and the fit of whose work would be altered by laying the warm hand on it.

Thanks to the Universal Grinder, and other machines never seen outside of America,* the production of accurate dies is a very easy matter, and this reduces the cost of manufacture to very little for most of the parts, including all the iron parts, as these must be in sheet form. For the other parts, turret lathes, jigs and form millers will do much work at low cost, but as a rule it may be said that for most work the method now coming into use, which depends upon the discovery of a process for casting hard and cheap alloys of the most complicated forms to size within $\frac{1}{1000}$ of an inch, is bound to extend itself. I have seen work, with surfaces lying in ten or eleven planes at different angles, with more than a dozen threaded screw holes, and all kinds of slots and openings at all sorts of angles, so that it would have taken a skilled American workman nearly a day to finish it (with jigs for clamping it on the machines in proper position all made beforehand and in place on the machines; or a full week without jigs, adjusting the piece to each machine by hand, to the degree of accuracy required), made all complete, correct to $\frac{1}{1000}$ of an inch, with not even a burr on a screw thread, so that any one of a thousand would fit into place with only a touch of a file to remove a parting mark, and costing for manufacture but *two* cents.

Of course, the dies are expensive, as they must be finished very carefully, and the casting is done under pressure and with non-expansible alloys of very hard and tough texture. But the cost of the dies will, in all but the very simplest cases, be rather less than that of the machine jigs, and, of course, the interest on machines, floor space and time of workmen are saved. I look for this to be the next great labor-saving advance.

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* This was written in 1898.

I cannot, however, go into the question of the methods of cheapening cost of manufacture, as that is an art by itself and one which takes considerable experience to learn. Of two men equally skilled in the knowledge of handling machinery, one will build a thing for $10, the other for a fraction of $1, the difference being due simply to differences in design, in making one part accomplish several functions and in making it direct and simple, though each apparatus may do exactly the same thing and in the same way. To designers I would say, work hard and all the time. Never let a piece of apparatus pass without seeing exactly how it functions, what the central idea was, how it was carried out, how you would have carried it out, how many operations and settings there were on it, what it must have cost, and, finally, whether you would have chosen that method at all. Moreover, read widely, and never lose a change in going over small shops, as some of the most ingenious devices in the world are in such places. I do not mean to say steal other men's ideas, because the fount of honor is in the commercial element of a nation, and spreads from thence, so that ideas of morality alter with conditions of trading, therefore we should be careful not to do anything which, if widely followed, would be injurious to the conduct of business. But form your mind by these good conceptions, just as the artist forms his by the inspection of masterpieces. And in doing so you will notice finally, after years of work, that your designs build themselves up like a piece of sculpture. Just as each individual part of a statue may be well done, and it yet does not hang together from different points, so that the impression of the whole is incoherent and repels; so a design is not good, however excellent the details, unless it gives that sense of complete adaptation of means to end which stamps the perfect conception. The designer is really an artist, in the higher sense of the word, in that his creations strike one with a keen thrill of intellectual joy, instead of appealing to the lower and more material senses and emotions. This artistic nature of the work is shown most markedly by the opportunity which is given the individu-

ality of the designer to assert itself, so that an experienced designer will say at once, on seeing a machine, "That was designed by so and so," or, "was modelled after his style by a man who had worked in such a place."

As regards economy of cost of copper and iron, that is, as a rule, easily solved. The method followed of late years in most American shops, where the designers are almost all university men, is that of designing the apparatus with a given set of dimensions and estimating the cost, then designing another and making another estimate, and so obtaining a rough curve from which the best size is chosen by the designer. Of course complete designs are not made, but only enough to get an idea of the cost. There are, however, always a great many variables, and sometimes a mathematical formula shows which are the proper things to take as variables, as for instance in the above discussion on the method of building apparatus of Class II for quick action.

To do this we need to know the relation between magnetic flux and magnetic force. This is given by Kennelly's law

$$\nu_i = a + \beta H,$$

that the intrinsic reluctivity ν_i is equal to a constant plus another constant times the gilbertivity H.

The intrinsic reluctivity is defined as the gilbertivity divided by that part of the weberivity due to the iron; *i. e.*, $B - H$, therefore,

$$\sigma = \frac{H}{B - H}$$

For practical weberivities H is small compared with B, and hence σ is practically equal to the reluctivity

$$\frac{H}{B}$$

This law occupies the same place in the magnetic circuit as Ohm's law does in the electric circuit; and is incidentally of great importance in that, as I shall show elsewhere, it enables us to decide between the different theories of

electricity. From the original law we may derive the following formulæ, which I have given elsewhere:

Since

$$\sigma = a + \beta H \tag{1}$$

$$\sigma = a \Sigma_0^{\infty} \beta B \tag{2}$$

$$\sigma = a / (1 - \beta B) \tag{3}$$

$$B = H / (a - \beta H) \tag{4}$$

$$H = a B / (1 - \beta B) \tag{5}$$

$$4 \pi n I = P\left[\frac{a l p}{s - \beta P p} + \frac{a' l' p'}{s - \beta P p'} + \right] \tag{6}$$

$$\frac{d B}{d H} = \frac{a}{\sigma^2} = a / (a + \beta H)^2 = \frac{a B^2}{H^2} \tag{7}$$

In Formula 6, which is for a compound circuit, such, for instance, as that of a dynamo, P represents the flux through the armature, l, s, a, β and p, the length, cross-section, coëfficients of the iron and leakage coëfficients of the different parts of the circuit.

The following are a few values of the coëfficients for different brands of iron:

Material.	a.	β.	Observer.
Sheet iron, A.	·0002375	·0000595	Author.
" " B.	·0002275	·0000654	"
" " C.	·00033	·000064	"
" " D.	·000213	·000056	"
Cast steel, A.	·00045	·000051	"
" " B.	·000315	·0000563	"
Wrought iron.	·00022	·000058	Hopkinson.
Mitis iron.	·00025	·0000575	Author.
Cast iron.	·00103	·000129	Hopkinson.
Improved cast iron.	·00090	·000106	Author.

It will be observed how much magnetic calculations are simplified by this law of Kennelly. We have also Steinmetz's formula for hysteresis, *i. e.*,

Loss per cubic centimeter per cycle $= \eta B^{1.6}$.

It will be of interest to note that I have found that a, β and η are connected by the simple equation

$$\frac{\eta\,\beta}{a} = \cdot 0007$$

which holds approximately for all brands of iron, from the softest transformer to the hardest tool steel, and thus, by making but two measurements of H and B for a sample of iron, we can derive all its properties. As I have learned that Dr. Kennelly has recently discovered other relations which show us what the physical meaning of Steinmetz's law is, it will be apparent that this difficult question is now pretty well cleared up. With these two equations and a knowledge of the watts per square centimeter which can be radiated by apparatus of the type we are considering, it

FIG. 12.

is simply a question of determining minima to ascertain the most economical cross-sections, etc. As I have elsewhere* given the method of doing this, I will not take it up now.

SPECIAL TYPES OF APPARATUS.

The sensitiveness of galvanometers is an interesting question, and, consequently, from what has been said above, it will be seen that a minute flattened head of very soft iron wire, suspended by a very long quartz fiber, the magnetic field being produced by the current it is desired to measure,

**Electrical World*, August 24, 1895.

as shown in *Fig. 12*, would be much more sensitive than any other kind if it were not for hysteresis. The air gap, of course, can be long, and the ring small, which will greatly reduce hysteresis, and prevent the bead sticking to the pole pieces.

The d'Arsonval galvanometer belongs to the third class, as also does the Kelvin, in the latter case the field being movable instead of the coil.

D'Arsonval galvanometers are very often wrongly rated. This is because the true equation for the motion of the coil is not complete, as generally given. As given, the terms mean that the impressed force is used up in accelerating the motion of the coil, in overcoming the air friction and in overcoming the restoring couple of the coil. There should be another term expressing the fact that a galvanometer is really a motor, and exerts a back voltage. The full equation should be

$$a\frac{d^2\theta}{dt^2} + (b + c)\frac{d\theta}{dt} + d\theta = 0.$$

To show how the neglect of this term gives entirely erroneous results, take a d'Arsonval, put it in series with a very large resistance and a 1-volt battery. Increase the resistance till we get a deflection of 1 millimeter on a scale 1 meter distant. Suppose the resistance to be 10^6 ohms. Then that is given as the sensitiveness if the period be ten seconds. But this figure is entirely and absurdly incorrect. The reason is that when we throw on the battery, the coil begins to move and generates a counter voltage, with the result that the voltage piles up at that spot, as it would with a motor, and we really have, say 10^{-5} volts there, instead of 10^{-6}, until the coil has slowed down. Of course, if we had simply applied 10^{-5} volts we would not have got anything like 1 millimeter deflection in ten seconds, as it might take several minutes. Now this is what happens when we use a d'Arsonval between the arms of a Wheatstone bridge, and to show that this matter is one of considerable practical importance, I would say that I have in my laboratory a d'Arsonval which has with some bridge ratios only 3 per cent.

of the sensitiveness obtained by the first method. The best d'Arsonval, therefore, is that which has the fewest turns and the finest suspension and the strongest field. For suspensions I would recommend phosphor-bronze wires or strips, as suggested by Ayrton and Perry, drawn as fine as possible, and annealed in a high vacuum by passing a current through it, as suggested by the writer (Mal. Phys., Frank. Inst., Feb. 14, 1896).

In Kelvin galvanometers, the needle is the most important point. Tubular needles were used by Prof. Very in designing the galvanometer used by Langley and have

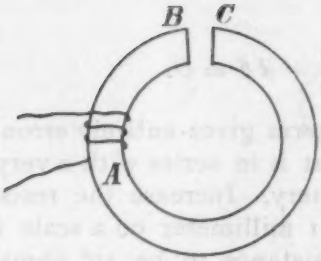


FIG. 13*a*.

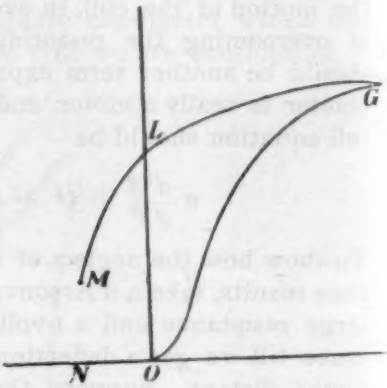


FIG. 13*b*.

since been generally adopted. The reason why tubular magnets are better than solid does not seem to be known generally, consequently it may be of interest to give it, using a method devised by Kennelly for determining the length of air gap to give the proper factor of safety for permanent magnets. This, put shortly, is as follows:

Magnetize the ring *A*, with air gap *B C*, *Fig. 13 A*. The induction will reach the point *G*, *Fig. 13 B*. Take off the current and it will fall to *L*. Now, if the air gap is 0·01 centimeter long and 50 centimeters area, its reluctance will be 1 / 5000. If the total flux at this point *L* is 15,000, this will mean that there is a gilbertance of 15,000 × 1 / 5000 = 3 between *B* and *C*, and we will take the potential at *B* as the

higher. Then there will be 3 gilberts trying to drive the flux from B to C, across the gap and also around the iron from B to A and A to C; *i. e.*, this gilbertance will exert a demagnetizing action. Therefore the flux will fall from L to some lower point M, where the demagnetizing force, *i. e.*, the gilberts necessary to force the flux OM across the air gap, will be less than 3. If now, when the flux across the air gap is NM, the gilbertance across the air gap is ON, it will

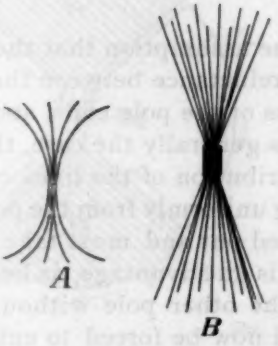


FIG. 14*a*. FIG. 14*b*.

FIG. 15.

not fall any further, as, if it did, the gilbertance across the air gap would be less than ON, and the point would tend to ascend the curve.

To apply this, suppose we magnetize a little magnet and, taking it out of the field, the flux at once falls till the gilbertance required to drive it across the air gap equals the demagnetizing gilbertance required to reduce the flux in the iron to that amount. How can we increase the remanent flux? Evidently by decreasing the reluctance through the

air, which we can do by giving greater area of cross-section at the junction of the iron and air.

This is what we do when we make magnets in the form of tubes.

Here is an interesting experiment. Magnetize a piece of darning needle, say 1 inch long, and suspending it, note its time of vibration in the earth's field. Then attach two very thin discs of pure sheet iron (very light), magnetize it again and take its time again. It will be found that the permanent magnetism is now from two to three times what it was before.

Evidently, considering this point alone, the most efficient magnet system for a Kelvin galvanometer would be as shown in *Fig. 14, A*, made by winding the wire on a round bar, tempering it and then cutting it (this better, though harder to do, than cutting and then tempering), then assembling and magnetizing. Still better is what I call the wheat sheaf magnet, *Fig. 14, B*.

All this, however, is on the assumption that the magnet is so long that the magnetic reluctance between the poles is determined solely by the size of the pole ends, and not by their distance apart. If, as is generally the case, this is not true, the question of the distribution of the lines comes in. Instead of the lines radiating uniformly from the poles, with short magnets, they are forced out and must take a longer path. It is evident that this is an advantage, as lines which would otherwise return to the other pole without linking themselves with the coil will now be forced to cut the coil. Theoretically, we could accomplish this leading out of the lines by putting thin sheets of iron between the layers of the galvanometer coil, if it were not for hysteresis. The next best thing to do is to use a magnet as short as possible and with as great magnetic hysteresis as possible. As tungsten steel has very great retentiveness, we can use quite a short, thick magnet compared with what we would have to use with ordinary steel, and so, for equal moments of inertia and weights, the short magnet would be much better. It is almost impossible to arrive at definite results, but with tungsten steel as at present supplied the proper form seems to

be that of an ellipsoid, with the major axis 1·5 times the lesser axes. A particularly promising form of galvanometer is that shown in *Fig.* 15, where *A* is a thin strip of mica, about a millimeter wide, *MM* are magnets fastened to the mica with a non-buckling cement, say beeswax with a few drops of glycerine, as used by Rowland, and *W W* are the windings and *H* the mirror. The magnets should be of tungsten steel, a few thousandths of an inch in diameter, with an *L*-shaped bit at the bottom of the mirror.

Another very promising form of galvanometer, in spite of the hysteresis, is that shown in *Fig. 16*, where *W W* are

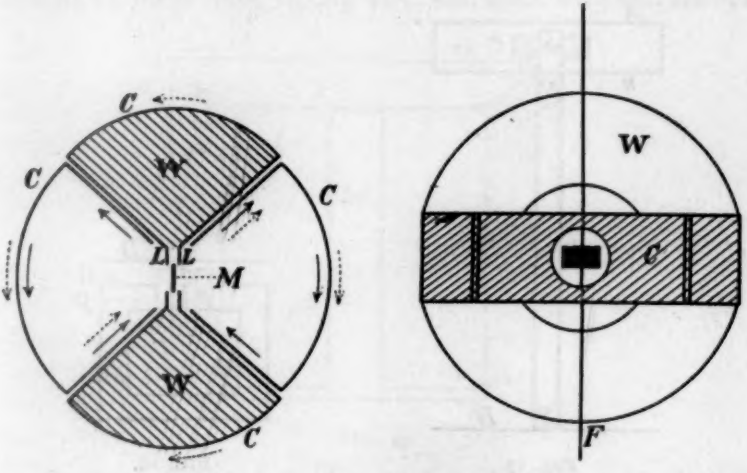


FIG. 16.

the coils, *M*, the needle, and *c c c c*, strips of sheet iron. The flux passes normally through the strips, as shown by the arrows, but, on exciting the coils, the flux changes to the path shown by the dotted arrows. This galvanometer would be of no use for quantitative measurements, but should be good for a telegraphic receiver.

The telephonic receiver belongs to Class III, but here it is a question of force rather than of work, as the telephone diaphragm does not move appreciably. Two of my students, Messrs. Bright and Davis, found some years ago that the motion of the diaphragm is certainly less than $\frac{1}{10000}$ of an

inch, and Barus later found that its motion was smaller than the wave length of sodium light. This force depends, of course, upon B^2. When the coil is not excited, the lines pass from S to S^1 (*Fig. 17*) through the air. The pole piece S being of soft iron, the drop of magnetic potential along it is small, and only a very small opposing gilbertance generated in the coil C will divert the lines, so that some of them pass from N to S at bottom of magnet without going through S at top of magnet and linking with the coil, thus reducing the value of B^2 at the air gap between S and the diaphragm.

Theoretically, still better results should be obtained by

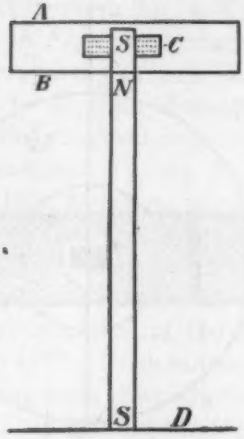


FIG. 17.

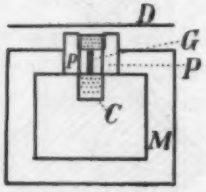


FIG. 18.

inserting another disc at B, loosely surrounding N. Also another disc, D, should be found to make some improvement.

Fig. 18 shows another design which I would suggest for a receiver, where $P\,P$ are soft iron pole pieces, G an air gap, M a permanent magnet and D a diaphragm. It works in essentially the same way, as also does the form suggested in *Fig. 19*, where M is the permanent magnet, C the coil and D the diaphragm.

It was mentioned above that the diaphragm does not move appreciably. Lord Rayleigh has shown that the amplitude of vibration of air particles need not be as much as

10^{-8} centimeters to produce sound. If we take the pull of a magnet on a diaphragm as 10 grams, this makes the energy expended in making the sound to be of the order of 10^{-11} joules. As a good galvanometer can be affected by an amount of energy of the order of 10^{-13} joules, there is still room for some improvement in the telephone receiver.

As regards telegraphic receivers, the principles which I have laid down above cover the main points, I believe, and as the paper is already pretty long, I will only refer to one or two details. As regards the line, the size of the line is governed practically by mechanical considerations, for to stand sleet storms we must have strong wire, and such wire will always

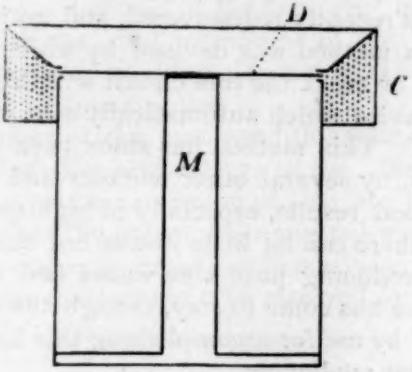


FIG. 19.

have ample conductivity for all practical purposes for all distances, even from San Francisco to New York, for it is doubtful if wire less than No. 8 B and S should be used for telegraphic purposes between places where a break-down of wires would be of much importance. A line of this size, 3,000 miles long, would, if of copper, have a resistance of say 8,000 ohms, and if we used up 100 volts in the line and 50 in the receiving instrument we would have nearly half a watt to work the receiver, which is more than ample.

The rule generally given for the voltage to be used upon the instrument is that it should equal that used up elsewhere, but I do not consider that practical, and it seems to

me that, under the conditions, if we have much leakage (which is good for some cases, but very bad for the writer's sine curve system), we should increase the voltage till the loss of voltage through increased leakage conductance drop equalled the increase of available voltage available at the receiving end. But for long-distance work, where we can keep the insulation reasonably high, or for all short-distance high-speed work we should use the system described by the writer in the *Electrical World*, September 15, 1899. To quote: "It does not seem to have been generally noted that the sine curve is a necessity for efficient telegraphy. In January, 1891, I designed and experimented upon the system of multiplex telegraphy (by resonant circuits) which Dr. Pupin has recently rediscovered, and noticed this fact. As a result a method was devised by which the operator did not make or break the line circuit with his key, but put in circuit a device which automatically sent out sine waves into the line." This method has since been adopted, with modifications, by several other workers and I understand with quite good results, especially in high-speed work, and I think that there can be little doubt but that the writer's method of producing pure sine waves and sending them out on the line has come to stay, though the original crude method used by me for accomplishing this has been superseded by better appliances.

But when we come to receivers we see that, under practical conditions, apparatus of Class II is the best, and we can devise such very simply by following the rules laid down. It all depends upon how you want your record. Personally, the writer would prefer the following method:

The receiver is that shown in *Fig. 16*. The needle carries a piece of mica, with a slot, vibrating across another slot at right angles to it, and light is thrown down through these slots onto a thin strip of common bromide paper, which is fed along thence into a developing and thence into a fixing bath and finally over hot drying rollers. The light would, of course, come from a powerful source, and with film of fair sensitiveness, I estimate 1,000,000 dots per second. The paper would cost 1 cent per 400 inches of

strip and would be permanent. The paper could all be tested before use and hence there would be no danger of failure.*

If mechanical records were preferred, a balanced microphonic contact could be used.

It is believed that for long lines, between important points, a combination of the writer's method of generating sine waves by a separate device, and using them for signalling, instead of making or breaking the line circuit with a key, together with the receiver shown in *Fig. 16*, and the photographic method of receiving, described above, will give the best results. If multiplex working is desired, then the writer's method of using resonant circuits, devised for the Pennsylvania Railroad in January, 1891, and experimentally tried, with the kind permission of Mr. William Stanley, in his laboratory at Pittsfield, during the spring of that year, will also be found of use.

The questions of the best conditions for rapid work, as regards the line; the best voltage to use; the best kind of insulators and best construction of line are of extreme interest, as also are the questions connected with cable working. But the paper is already sufficiently long, and the discussion of these matters must be reserved for another time.

Stated Meeting, held June 20, 1900.

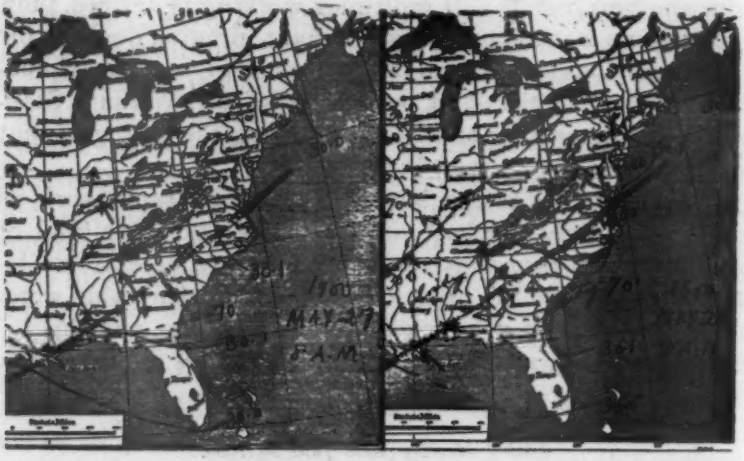
THE SOLAR ECLIPSE OF MAY 28, 1900.

The following notes of observations of the recent solar eclipse made by members of the Institute were presented at the stated meeting of June 20th.

MR. H. M. WATTS, who devoted his time to a presentation of a few of the meteorological facts connected with the eclipse, began by calling attention to the general weather conditions which prevailed on the morning of the eclipse and the day previous, which were made clear by the

*This lecture was delivered before the publication of the method of Messrs. Pollak and Virag.

projection of two weather maps (8 A.M., May 27th, and 8 A.M., May 28th) on the screen. Mr. Watts called attention to the remarkable positiveness and accuracy of the Monday morning forecast of Prof. Willis L. Moore, of the Weather Bureau, made twenty-four hours in advance, which he ascribed to Professor Moore's expert ability in the balancing of weather probabilities, as the conditions were really such as to make so positive a forecast for the eclipse conditions as Professor Moore sent out on Sunday morning at 10 o'clock a very difficult problem. Mr. Watts explained the weather maps at some length and showed that on the morn-



Weather conditions on the morning before and the morning of the eclipse, showing the anti-cyclone (area of high barometer) overlaying the path of the eclipse shadow.

ing of the eclipse over the entire eclipse tract there was an area of high pressure very little above the normal of 30 inches, which insured remarkable steadiness and a general even circulation of the air from New Orleans to Norfolk. There were no clouds along the entire line of totality in the United States, the weather on Monday being as Professor Moore predicted on Sunday, the best "seeing conditions" possible.

Mr. Watts then took up the question of the weather changes that occurred during the eclipse and pointed out

that they were comparatively slight indeed in this eclipse and not as marked as those that have occurred before, or as the general impression is usually the case. Theoretically, the chilling of the moon's shadow should cause a heightening of the pressure and a change in the wind velocity and in its direction of movement. At Norfolk, where Mr. Watts saw the eclipse, there was no change in the wind's direction at all, and but a very slight increase in the velocity during the eclipse. The wind was from the south all the time. As to the temperature changes, the thermometers registering air temperature showed very little change. At 8.23 at Norfolk, at the Weather Bureau office, the dry thermometer was 69·04°; at 8.53, 68·05° (totality); at 8.58, 68·02°, after this slowly rising to the normal for the day. The wet bulb at 8 o'clock was 62·05°, with a relative humidity of 69 per cent.; at 8.48, 60·02°, with a relative humidity of 55; at 8.53, 60·05, with a relative humidity of 56; at 8.58, 61°, with a relative humidity of 57. These changes were hardly appreciable so far as the general air temperature went, but at Virginia Beach there was a more decided fall, the thermometer falling from 69° at 7.45 steadily downward to 59 during totality at 8.55, rising again to 69 at 10 o'clock. The dew also formed at Virginia Beach, and the sea breeze from the east which was blowing early in the morning under the prevailing wind current from the south ceased during the eclipse, the wind shifting slightly between south and southeast, also varying very slightly in velocity, an increase being noted during totality.

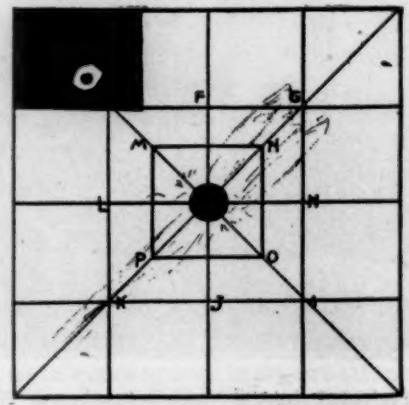
In discussing the slight changes in the air temperature during the eclipse as compared with the general sense of chill reported by so many observers, Mr. Watts reported that he felt no chill on the roof of the Weather Bureau at Norfolk, and attributed the very slight air change there to the fact that Norfolk was a very large city, where the air temperatures vary much more slowly than in the open country. At any event, however, the general air temperatures would never show the marked change which seemed to take place to the observer, and the peculiarity of this phenomenon, which Mr. Watts said had been the subject

of a great deal of discussion, seemed to him very simple, as the great chill reported was due, not necessarily to any unusual falling of the air temperatures, but to the chilling of the skin of the face by the removal of the sunlight. Mr. Watts pointed out that it was well known that the thermometer in the full sunlight would show a temperature varying from 20° to 30° to 40° above the temperatures of thermometers enclosed in shelters which only gave the air temperatures. Hence the temperature of the skin in full sunlight would be much greater than the temperature of the skin with the sunlight cut off, and it was to this physical effect on the superficial layers of the skin that Mr. Watts attributed the sense of extreme chill which, associated with the extraordinary spectacle of the eclipse, through association of ideas became possible of great subjective exaggeration.

Mr. Watts said that he saw no shadow bands at Norfolk, but judged from the various reports that the belief that these were optical illusions was forever dispelled, although no less an authority than Professor Newcomb, up to the time of this eclipse, thought that the shadow bands might have no real existence. The evidence during this eclipse, Mr. Watts said, suggested that they were meteorological phenomena; light effects due to air currents. He read a letter from Prof. Frank L. Bigelow, of the Weather Bureau, who said that, while not prepared to report, observations had been made which would prove very interesting and instructive and had disclosed new phenomena. Mr. A. Lawrence Rotch, of the Blue Hill Observatory, was quoted in a letter saying that while the shadow bands still puzzled him, it must be admitted that they were of atmospheric origin, and Mr. G. W. Pickard, acting for Blue Hill, in a note to Mr. Watts, reporting on the shadow bands as seen at Virginia Beach, wrote as follows:

"As seen by the writer, the bands were at first wavering shimmers of light and shade, very like the reflection of sunlight from the surface of slightly rippled water to a screen. Within a few seconds they became more distinct, with an apparent velocity of 6–12 feet per second toward the south-

west, the bands themselves being at right angles to this direction. They became more and more distinct until the moment of totality, during which no bands were noticed. The bands reappeared almost simultaneously with the third contact, very distinct at first and gradually fading away with the increasing light, identical in appearance with those before totality, save that the distinction was in reverse order. Perhaps the best idea of the wavering motion of the bands can be obtained by walking past a double line of picket fence, noticing the flicker as the relative positions of the pickets and the open spaces between them conflict. The bands were first observed one minute and thirty seconds before totality and lasted about the same length of time afterward."



Drawing of the corona made at Norfolk, contrasted with small photograph made at Cape Charles, Va.

Mr. Watts, in conclusion, presented a diagram of the appearance of the corona, drawn by him at the time of the eclipse, which showed a broad flame-like appearance for the upper equatorial extension and a more pointed form for the lower equatorial extension, the former stretching about three diameters and the latter four.

MR. A. E. KENNELLY:—Mr. J. M. Justice and I went to Virginia Beach* to observe the eclipse as sight-seers and

*Near Norfolk, Va.

amateurs. We took with us a copying camera with 6 feet of extension, and 8 inches by 10 inches double coated and backed Seed's plates. We arrived at Virginia Beach on Sunday the 27th ult. Early on the morning of the 28th we selected a position on a small sand dune about 30 feet above sea level, on the western side of the railroad switch at the northern vertex of the railroad delta, which is about half a mile below the Princess Ann Hotel. Here we set up a rough platform at about 45° elevation for the camera to face the sun at totality. This we fitted with the back combination of a 3 inch aperture Dallmeyer lens of 49 inches

Camera and oriented sheet at Virginia Beach, near Norfolk, Va.

focal length. Being used without a diaphragm, this lens gave us a focal length divided by aperture of $f = 16{\cdot}3$, approximately. A smaller camera 6·5 inches by 8·5 inches on a tripod was also used, of 10 inches focal length and $f = 16$.

A metronome was employed and timed to give sixty beats per minute. By its aid we were enabled to count out the period of totality. A stereopticon sheet 9 feet square was oriented with the aid of a sling compass and spread horizontally on the sand, fastened to stakes at the four corners.

We were joined by Professor and Mrs. C. F. Himes, Miss Mary M. Himes and Miss Anna M. Himes, who assisted us in making our observations.

The sky was clear and cloudless until about fifteen minutes before totality, when a few light cirrus clouds appeared some 15° above the northern horizon. Otherwise the sky remained cloudless throughout the eclipse.

After the first contact no noticeable effects were observed until about thirty minutes before totality, when the diminishing sunlight began to produce a reduction in the apparent warmth of the body, and the color values of the landscape commenced to change from the bright tints of full daylight to deeper and more sombre tints, differing perceptibly, however, from those which would accompany the obscuration of the sun to a corresponding extent by clouds. The progress of the moon's shadow across the sun was followed, both upon the ground glass of the camera and also with the aid of smoked glasses.

A watch was kept on the sheet for shadow bands, but none were observed until about thirty seconds before totality, when they became distinctly visible; the general illumination was then quite low. They appeared like ripple marks in rapid agitation. They formed ripples like undulating dark cords on the general light surface of the sheet. They were not so sharply defined, either in the direction of their wave crests or in the spacing between successive waves, as to make accurate observations possible, but, in general, the waves had their crest lines parallel to each other. Each crest line was not a straight line, but a line undulatory about a mean line which might be regarded as straight. These mean crest lines were diagonal to the sheet, or northwest to southeast, while the direction of the motion seemed perpendicular to the direction of the crests, or southwest to northeast, and progressing from the southwest to the northeast. The distance between successive waves, or the wave length, appeared to be from 1 foot to 18 inches, and there appeared to be about six waves passing any point in each second, or what would correspond to a linear velocity of 6 to 9 feet per second. The contours

were neither sufficiently sharp, nor the spacing sufficiently regular, to warrant any precise statement, however, as to the velocity. The waves seemed complex and composite, and the spaces between main crests were usually filled with fainter ripplings. The appearance of these shadow bands was similar in character to that which is produced by the falling of sunlight upon a bright floor after passing immediately over a highly heated register. The bands continued visible until the arrival of totality, when they were completely lost in the darkness.

The onset of totality was marked by the appearance of a deep blue-black gloom almost cloud-like in its appearance, which appeared to settle steadily upon the landscape, but no moving shadow of the moon could be seen from our point of observation.

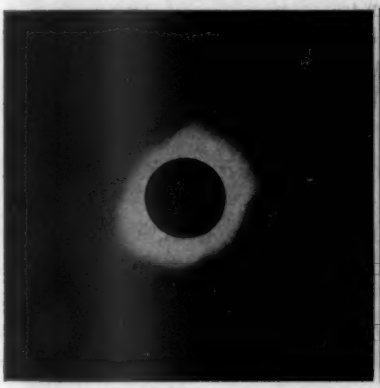
There was a very faint sea breeze; that is to say, a very faint easterly breeze during the interval between first contact and totality, accompanied by a general light southerly breeze. About the period of totality the sea breeze died away, but the smoke from chimneys showed that the light southerly breeze still persisted.

The moment at which totality commenced appeared to be sharply defined to observers watching either the sheet or the landscape, owing to the sudden loss of light. At the same instant the corona leaped into view. It stretched out, as judged by the naked eye, to a distance of about 2·5 diameters from the moon, both at the eastern and at the western limb. The contrast of the black moon against the corona was very vivid. The general illumination at this time was very feeble, but it was possible to read ordinary print without difficulty. Over the sea on the eastern horizon was a horizontal rosy-red strip of sky 2° or 3° in height, into which the moon's shadow did not enter, and from which some diffused light was scattered over the general landscape. Mercury and Venus were distinctly visible.

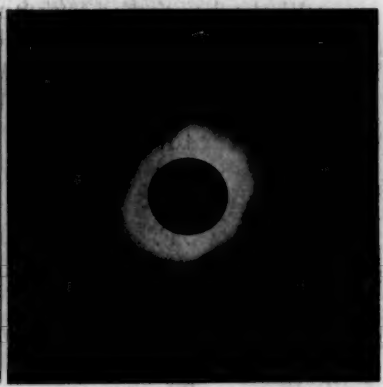
The corona had a pale silvery sheen like moonlight shining through gossamer threads. It was colorless and resembled in general dimensions a capital A, set on its side thus, ◁, with the moon on the cross-bar.

The first photograph was taken five seconds after the commencement of totality with an exposure by metronome of one-half of a second. The second photograph was taken fifteen seconds after the commencement of totality with an exposure by metronome of three-quarters of a second. These two pictures are here reproduced. After the eclipse was over an improvised dark-room was prepared, the plates were removed from the plate holders, marked on their top sides and packed in a separate box.

Just as the sun's edge flashed out suddenly over the moon's limb, marking the end of totality, the eye being sensitive from the preceding darkness, it became apparent,



Photograph No. 1. 5 seconds after commencement of totality. Exposure, ½ second.



Photograph No. 2. 15 seconds after commencement of totality. Exposure, ¾ second.

without the aid of a telescope, that the effulgent edge was not a geometrical segment of a circle uncovered by a circle, but a series of bright dots uniting into a circular segment.

Immediately after totality shadow bands were again observed for about thirty seconds. They appeared somewhat more distinct than those which preceded totality. The general direction of the wave crest lines appeared to be about the same as before totality, but the direction of progression seemed to have reversed or to be from northeast to southwest. This apparent reversal of the progression may have been only imaginary, although it was the general impression of the observers.

Dew was deposited upon the external wooden surface of the camera during the eclipse, and was also deposited upon grass and other objects in the vicinity.

The plates were developed by Mr. Justice in pyro solution. The diameter of the moon's image on these plates is 0·42 inch. Notes of these observations were written out shortly after the eclipse. The following are also notes independently written out, very shortly after the eclipse, by Miss Anna M. Himes, concerning the shadow bands:

"(1) They were visible for about equal times both before and after totality.

"(2) They appeared brighter after totality, which was most likely due to the greater sensitiveness of the eye.

"(3) They were long waves with shorter waves superimposed.

"(4) The direction of the waves was the same both before and after totality.

"(5) The waves advanced in opposite directions before and after totality."

PROF. CHAS. F. HIMES remarked that to him, as one of the members of the government expedition organized and so efficiently conducted by Prof. Henry Morton, then Secretary of the Franklin Institute, to observe and photograph the total eclipse of 1869, comparisons of the eclipse of this year with that of 1869 naturally suggested themselves, as well as other incidents in this connection that might not be without interest, at least, to members of the Institute. First he would say that the remark at the close of the report of the section stationed at Ottumwa, Ia., made by him, that the experience gained would be of service in a future observation, did not apply, except in a very general way, after the lapse of thirty years, as the points of interest had changed, entirely new problems had arisen to which instrumental aids had had to adapt themselves. Then the spectroscope was a comparatively new introduction and did settle some questions. The experience of that date, however, that did service in force was the necessarily unsatisfying character, at that time, of the observation of the phenomenon as a whole, and the resolution, if the opportunity should again

offer, not to be controlled, at least during totality, by the requirements and responsibility of special observations.

It was a matter of congratulation, therefore, soon to discover that Dr. Kennelly and Mr. Justice, with whom it was his good fortune in many ways to be associated, were so completely prepared at all points that they were amply able to manage the observations they had proposed for themselves without necessity of offer of assistance from him, at least during totality. In 1869 wet-collodion was dominant, with its requirement of well-constructed dark-room, all the impedimenta of baths, solutions, etc., as well as the details of preparation and development of plates on the ground. It was at best slow, rigid and unaccommodating. Those in the dark-room (Mr. John C. Browne and Mr. W. J. Baker) had to be satisfied with the merest glimpse of totality stolen from the door of the dark-room. As there were no instantaneous shutters then, so common and mechanically perfect to-day, it was fortunate that the Institute had among its members the scientific, ingenious and skilled Joseph Zentmayer, always ready to contribute of his valuable time and peculiar ability to assist in purely scientific work. He devised and made shutters for the cameras attached to the several telescopes, with which exposures could be made for small fractions of a second during the partial phases, and time-exposures during totality, and withal connected electrically with a chronograph upon which the times of exposure were recorded by the click of the exposure slide. Other astronomical as well as photographic demands were equally well met by him, and a modified Huyghenian eye-piece afforded images of the sun about 2 inches in diameter. The expedition was divided into three sections, one each at Burlington, Mt. Pleasant and Ottumwa, Ia. Weeks were spent in experimenting and practicing on a vacant lot in West Philadelphia, and the parties set out ten days before the date of the eclipse for their several points of observation. This very general statement will suffice to show the relation of the Franklin Institute to the observation of the eclipse of 1869. Full details may be found in the reports published at the time

in the *Journal* of the Institute, and also separately by the government. The latter, with larger liberality than at present, without the expenses of the Spanish War and expansion, appropriated $5,000 for the expedition, and the railroad companies, under the inspiration of Mr. Thomas Scott, then President of the Pennsylvania Railroad, supplemented this provision of the government by free transportation of the observers and their apparatus in a new first-class car, specially fitted up for their accommodation, carried without change, by way of the bridge at Burlington to the several points.

This was not so small a matter at that time, when through trains were not run beyond the Mississippi. The money value of this favor of the railroads was estimated at $1,500. There was, of course, the usual anxiety about the weather, without the comforting assurances from our present reliable Weather Bureau alluded to and with rains and violent thunder storms up to the very day of the eclipse. But the hour of the eclipse found a perfectly cloudless and bright sky and all adjustments and preparations complete. But after everything has been thought of and done in such cases, there is always room for a residuum of one or perhaps several minor omissions that may imperil success and neutralize the most elaborate preparations. Nothing more than such an observation as this serves to impress the fact that nature does not recognize the terms "trifling" and "minor," frequently applied to any of her conditions. The more elaborate the preparations, the more points at which disturbing factors may enter. The chronograph seemed to be in good working condition. It was also to be used by Prof. Stephen Alexander, of Princeton, who had observed several previous total eclipses, and, accompanied by General Halsted, who had recently erected a fine observatory for Princeton College, was at the same point. As it was in the hands principally of volunteer assistants, there seemed to be big possibility that at the critical moment something unexpected might happen. Arrangements were therefore made for timing the exposures independently of the chronograph, by means of a chronometer, the sharp click of the exposure

slide favoring this. It proved fortunate, as the chronographic record became defective in a very unexpected way. Professor Alexander sat beside the seconds-tapper and, as had been agreed, quietly slipped his hand over to use the key to interpolate the time of an observation he was about to make upon the fillet, between the marks of the seconds, and the tapper, thinking the professor was about to assume his occupation, stopped tapping, and the record of seconds on the fillet ceased. The psychological conditions, though not without their humorous side, are not to be left altogether out of account. As totality approached, Mr. Zentmayer was at the camera. He had scientific training, and was as cool and self-controlled as most of us. He had just made the happy exposure which captured Bailey's beads. Then, in the darkness that suddenly enveloped the whole scene, as the corona burst forth, with its attendant appearances, both gazed at it. Professor Himes, not hearing the click of the slide announcing exposure, turned to Mr. Zentmayer to see him standing, with arms extended, gazing fixedly at the phenomenon, apparently entirely oblivious that exposures were to be made, and that the time was counted by seconds. A word to him broke the spell, and he turned hurriedly to the camera. Still no click telling of exposure came. On inquiry, Mr. Zentmayer replied that it was too dark to make the adjustment of the exposure slide required by the feebly actinic corona. The lantern, very thoughtfully provided for such a contingency, hung above his head, but unlighted. The minute thus lost was long enough to permit a whole train of thoughts and feelings of mingled disappointment and mortification that through an oversight so apparently trifling all should have come to naught. The three negatives of totality secured in the remaining time, the longest exposure being sixteen seconds, were regarded as very successful for that time, the one last taken being especially interesting on account of the suggestion of the corona which it gave.

Professor Schellen, in his work on the Sun, and in that on Spectrum Analysis, gave it a special place of honor, and others make particular mention of it. It is easily seen from

the positives from these, thrown upon the screen, how much less they tell than the negatives of to-day with the more sensitive and accommodating dry plate. Attention was especially directed to the slide of Bailey's beads, the merest points of light left by the ragged edge of the moon, yet sufficient to restrain the outburst of those grand features that separate totality infinitely from all partial phases, and make it an incomparably grand, unique, indescribable phenomenon. This seemed to take a deep hold on the observers of that day. An effort was made by Mr. Zentmayer to express it by means of a mechanical slide. As thrown upon the screen it first presented a photograph of the sun of that day with some well-defined spots; a circular disc representing the moon gradually passed over it until the last faint line was cut up by the ragged edge, when corona and the attendant red prominences surrounding the black moon burst forth suddenly and unexpectedly. It is the grandeur and suddenness of this display that many who have never witnessed it fail entirely to comprehend. In this connection he had hesitated to compare the eclipse of this year with that of '69. It was this general view which he desired to hold himself perfectly free to observe. But a second view of the grandest phenomenon may reduce its impressiveness and disillusionize an observer; but the general reports of the eclipse just passed, and comparison with others of recent years, emboldened him to say, that whilst it could not fail to impress permanently the mind and heart of every one privileged to witness it, yet in some of its features it fell notably behind that of 1869. The red prominences, or protuberances, were not as numerous nor as large. They were a matter of general comment and remark, even as seen by the unaided eye in 1869. The corona was not of the same shape, as can be seen from the slides of the recent eclipse and the totality slide of 1869, which, although not photographic, was from the most generally accepted drawings. Neither did it have the same extent, nor manifest to the unaided eye the texture or movement of the former one. The sudden darkness of totality did not seem as intense, and, as a consequence, the stars did not seem to spring out with the same brightness,

and the apparent reduction of the extent of the corona and absence of character may be in part accounted for by this fact. Nothing of all this, said by way of comparison, is to be understood as in any degree detracting from the gratification of witnessing this grand exceptional phenomenon under circumstances so favorable. Others were present who took part in the former observations, from whom it would be a pleasure to hear. As to the "shadow-bands," there were so many other unmistakable and indisputable points to occupy the very limited time, and he was so skeptical in regard to them, that, unless provision had been as carefully made by Doctor Kennelly to look for them, he would have neglected them entirely; as it was, he must now add his testimony to that of the others as to their existence, and suggest that they may repay future more careful observation and study.

MR. ARTHUR T. COLLINS:—Our party consisted of Prof. G.A. Hoadley, Mr. Chas. U. Bedell, Professor Price and myself. We located at Kelford, N. C., which is exactly on the central line of the shadow path. The objects we had in view were threefold, namely, photographing the corona, measurement of the position of the coronal line, and observation of shadow bands. Professor Hoadley and Mr. Bedell obtained six negatives of corona and prominences, some of them quite clearly showing coronal streams and two or three prominences of the horn variety, one being about 25,000 miles in height. Their instrument consisted of a 3-inch telescope objective, mounted in a camera box, the length of which was equal to the focal length of the lens. This was mounted on a polar axis and operated by screws in Decl. and R.A., the instrument being allowed to rest during exposure.

My part of the work was to measure the position of the coronal line. In order to do this I used a spectroscope, containing one compound Rutherfurd prism by Brashear, mounted equatorially and driven by hand. The telescope was moved on same mounting

$$\frac{f}{a} = 13.$$

I used a radial slit set at point of second contact. At the moment of totality the dark lines turned to bright lines for about one and a half seconds in time. This is due, as is well known, to obtaining at that point the spectrum of the chromosphere, which contains the elements in the form of glowing gas, and which ordinarily produces the dark-line spectrum. I noted also that the bright lines of the chromosphere were of quite different lengths, most of them being only dots, while others appeared to be ¼ inch long, showing that different elements rose to different heights above the surface of the sun.

Previous to making my observations the pointer in the micrometer was set on the line γ 5317 (1474 K). This line was bright during the flash in common with others and faded out when the moon had passed over the chromosphere. Then I saw the coronal line take its position just above or toward the violet. The pointer was moved up and the measurement taken. I make the new position to be γ 5304, and believe this is near the true place. It seemed that all the lines in the field of the spectroscope flashed bright, but the time was so short that only a guess as to the truth of this could be obtained.

We had hoped to photograph the shadow bands, but found them quite too fleeting and indistinct to even attempt it; but on their second appearance we laid dowel pins, painted black, on the sheet, to indicate their direction and distance apart, and photographed these together with a measure in feet and inches, also a north and south line. We found the shadow bands to be 1½ inches wide and from 7 to 9 inches apart, the crest of the wave or band being irregular in shape, having the appearance of ripples on water caused by wind and moving at the rate of probably 10 feet per second, the crest of the wave moving in the direction of the path of the eclipse at both appearances.

MR. FREDERIC E. IVES:—My son and I went to Norfolk, and from there to Virginia Beach, to see the eclipse. We took with us a 3-inch telescope, two spy glasses, opera glasses, colored glasses, a spectroscope and a polariscope, but no photographic apparatus. We thought it would be a

waste of time to make small photographs with ordinary camera or small telescope when some of the eclipse expeditions were so much better equipped for such work.

I had thought of attempting to make a Kromskop color photograph, which, if it could be successfully accomplished, would be extremely interesting, and have some real value as a record, provided that the red prominences were as large and striking in appearance as they have been on some occasions; but in order to make such a photograph, it would be necessary to employ a clock-driven equatorial mount, which I could not readily obtain when I wanted it, and this fact and the knowledge that the prominences were not likely to be very striking at a period of sunspot minimum, led me to give up the undertaking.

We missed the shadow bands, and observed nothing but the waning light and relief from the sun's heat until almost the moment of totality, when my son, who was at the telescope, remarked that he had a beautiful view of the Bailey's beads. At the moment of totality he threw aside the dark glass and examined the prominences and the structure of the corona.

I was using the spectroscope at the commencement of totality, and after seeing the bright-line spectrum, viewed the eclipse through an opera glass, looking particularly for the prominences, which, however, were so much smaller than I expected, that I did not then see them at all, but noticed particularly the form and pearly effect of the coronal light and the appearance of what we called, for want of a better name, "the lines of force," simulating the arrangement of iron filings about the poles of a magnet. My son reported a most beautiful wispy structure visible in the telescope, and small prominences which were not crimson, but suggestive of bits of incandescent wire.

We then exchanged places, and what impressed me most in the telescopic view was the resemblance of the prominences to the color of burnished copper reflecting sunlight. Other observers have since stated that they did not appear to them to be crimson or red, but a sort of brick red or pink. They were not sufficiently large and striking

to have shown to advantage in the Kromskop in a view showing the entire corona, and my decision not to attempt such a photograph was therefore justified. The two largest prominences, which were quite near together, looked like loops of fine wire (we were using a low-power eyepiece), and we both noticed a peculiarity in the focussing which in itself would have indicated to an optician that the light was made up of widely separated bright lines or bands in the spectrum.

The total phase passed all too quickly, and we noticed that the corona remained visible for some seconds. We noted the brilliance of Mercury, and the orange color near the horizon, and that the light appeared very much stronger than that of the brightest moonlight, apparently quite sufficient for reading fine print; but we made no important observations, and did not go there expecting to make any.

MR. JOHN CARBUTT:—It would be presumptuous in me to try to add anything to what Professor Himes and the gentlemen preceding him have already said on the scientific aspect of the late eclipse, but I will make a few remarks on the use of photography in eclipse observations. Thirty years has brought quite a change in processes used. In 1869 I was invited by Prof. Henry Morton, the then Secretary of the Franklin Institute, to accompany his section of the observers organized by the Franklin Institute to Mount Pleasant, Ia. At that date I was residing in Chicago. I took with me my wet-collodion outfit; our location was in the Fair grounds, a room in one of the buildings was used as a dark-room in which I prepared and developed the plates as fast as exposed, Mr. Ranger, of Indianapolis, with Mr. Clifford, of Philadelphia, carrying the plates to Professor Morton, who was assisted at the telescope by Mr. E. L. Wilson and James Cremer. Of course, I saw nothing of the beginning or ending of the eclipse, but during totality I was called out to see it. I must leave you to imagine my sensations when, after entering the dark-room with bright sunlight outside, I emerged into what by contrast was almost Cimmerian darkness. The men around the telescope were barely discernible. I may here say that

I have the camera and amplifying lens made by the late Mr. Zentmayer, used at Mount Pleasant, which was presented to me by Professor Morton.

After the eclipse was over I made a stereoscopic negative of the party, an enlarged copy of which I here present to the Institute, also an enlarged print from the negative of partial phase of the late eclipse I made at Wayne Junction while the sky was full of clouds. The sun's image on the negative is 5 millimeters in diameter, and was made on a triple-coated plate, backed, with the back combination of a euryscope lens of 22 inches focus, stop F/44, Prosch shutter, speed about $\frac{1}{25}$ of a second. Astronomers photographing the late eclipse have availed themselves of the improved methods in preparing gelatine dry plates, and as a dry plate maker, I was called on to make plates of various speeds, from single-coated slow emulsion to double and triple-coated plates with different speeds of emulsion; I also made for the Smithsonian Institute circular celluloid plates 16 inches in diameter, of $\frac{1}{16}$ inch thick. All the glass plates were backed with black backing and prevented halation entirely.

MR. S. A. TATNALL:—What has already been said by those who have just spoken corresponds so nearly with the impressions which the eclipse made on me, that I fear I can add very little of interest. I have not heard, however, any expression as to the degree of darkness during totality, which I found to be rather difficult to judge. This being my first experience with total eclipses, I have little to compare with, but it seemed to me to be somewhat darker than full moon. I doubt if I could have read fine print of a newspaper.

The negative from which the slide was made was taken at Norfolk, Va., with the back combination of an 8 x 10 Leclair lens, having a focal length of about 24 inches and aperture of $1\frac{1}{2}$ inches. I did not use any stops, and exposed one second on a Cramer Crown plate, backed.

The plate was developed with metol, weakened with water and a liberal quantity of bromide added.

Mining and Metallurgical Section.

Stated Meeting, held Wednesday, December 14, 1899.

SOME PROBLEMS IN DEEP COAL MINING.

By H. M. Chance, Philadelphia, Pa.

In mining coal seams lying at considerable depth beneath the surface the engineer is confronted by difficulties not present in shallow mining. Modern American mining practice requires large output as the first prerequisite of a successful mining operation, for without this it is impossible to mine at a cost per ton low enough to compete with the more shallow mines.

As depth is reached in any coal-field the quantity of explosive gases given off by the coal increases rapidly, requiring a larger quantity of air to properly ventilate the workings. This is the problem of greatest importance, how to supply adequate ventilation, for without abundant ventilation it is impossible to open and work enough rooms or chambers to produce the desired output.

As the depth increases, the roof of all coal-beds, being subjected to greater pressure from the increasing mass of overlying rocks, is more likely to fail, and in deep mines we generally have what the miners call a "bad roof," although the roof may really be a very good one but unable to stand the enormous pressure which comes upon it.

A "bad roof" means increased cost of working, for not only does the roof break and fall in the rooms or working places, but on the main haulage roads and airways as well, involving heavy expenditures for timbering, for the renewal of timber, and for labor in clearing away such roof-falls.

Again, as depth is gained, the risk of closure of the workings by "squeezing" or crushing of the pillars of coal left to support the roof, rapidly increases with the increasing weight of the overlying rocks.

The three important problems presented by deep coal mining then are:

(1) To provide ample ventilation, which may be increased as the area of the workings enlarges.

(2) To reduce the cost of maintenance due to roof-falls, especially roof-falls on gangways and airways.

(3) To limit the possible damage from "squeezing" and to prevent "squeezes" from closing the main haulage roads and airways.

Several systems have been devised and used for providing adequate ventilation under such circumstances (among which may be noted the "Three Entry" system which is largely used), but they all are open to serious objections.

These systems generally use the main haulage roads as intakes for the ventilating current, and these must then be driven very wide to give the necessary cross-sectional area of airway, thus increasing the cost of timbering, and risk of damage from roof-falls. To secure additional area the return airways are either driven double (as in the "Three Entry" system) or of large cross-sectional area, which is objectionable, not perhaps because of increased roof-falls, but because of increased first cost, and a slower rate of developing new territory.

The risk of damage to main roads and airways by "squeezing" is now generally guarded against by leaving a thick pillar of coal separating these from the working places, this pillar being broken only by necessary openings for roads or airways.

It is evident from the outset that the only way to reduce the cost of maintenance of the main haulage roads, and save timber, and the delays and accidents incident to roof-falls is to drive these haulage roads as narrow as possible. It often happens that a gangway 9 or 10 feet wide may require no timbering, the roof standing for years, while if driven 14 feet wide it might require heavy timbering throughout or give constant trouble from roof-falls.

Now, if the main haulage roads are driven narrower to save timbering, cost of maintenance, and delays and accidents from roof-fall, it is evident that they cannot be used

as the main intakes for ventilation, as they will be too small to carry the increasing volume of air required as the workings extend to long distances from the shaft.

The system described below which has been devised to overcome these difficulties should effect a considerable economy in timber, maintenance, operation and first cost of dead work, in addition to providing facilities for efficient ventilation, and reducing the risk of accidents from roof-falls, transportation and explosions. I will attempt only a description of the principal features of this mining method, the details of application of course varying with the conditions present.

The main haulage road (with its airways), whether this be a water-level gangway, a slope to the dip, a plane to the rise, or a face entry driven across the dip, is driven ahead into the new territory, as in present practice, and the water-level gangways or butt entries (each with its airway), from which the chambers or rooms are to be opened, are located at intervals of 300, 400, 600 feet or more as desired.

This main haulage road and airway are driven as narrow as possible to prevent failure of the roof and save timber, a good pillar of coal being left between, broken at intervals by small cross-cuts, such as are essential for ventilation while they are being driven.

Upon driving the desired distance, a water-level gangway (or butt entry) and airway is opened to right and left, and from these, on each side, two rooms or chambers are opened and work back to the last gangway. These rooms or chambers are driven parallel to the main road and airway, an unbroken pillar of 30, 40 or 60 feet separating the first room from the road or airway and a pillar of good thickness separating the two rooms on each side. When these rooms are worked back to the last gangway and holed through, we have, in addition to the first two openings driven, that is, the main road and airway, four wide parallel roads or airways. The outside room on each side is used as a return airway and the inside rooms as intakes, and the original main road and airway are also used as intakes.

The inside rooms may be driven 16 or 18 feet wide and the outside rooms 22 to 28 feet wide.

The inside rooms, in addition to their use as intake airways, are also used as manways or travelling ways, so that miners need travel neither along the haulage road nor in the return airways.

A thick barrier pillar of coal is left beyond the outside rooms, separating these from the working places to protect these airways and the haulage road from damage by squeezing.

This system gives four straight and continuous intakes and two large return airways throughout the length of the main haulage road. The mine workings on each lift or gangway are ventilated by a separate split taken in through the gangway and workings, and returned through the airway to the main return.

The two intake chambers being used as travelling ways may require center props. The main haulage road will require little if any timbering unless the roof be very weak.

In the absence of a diagram and to simplify the description as given above, the method may be described as a modification of that in ordinary use where a barrier pillar is left on each side of the main haulage road and airway, to separate these from the rooms or working places, this modification consisting of transposing a pair of rooms on each side of the barrier pillar from a position outside this pillar to a position inside the pillar, and locating these pillars a corresponding distance away from the main haulage road.

BOOK NOTICES.

Hydraulic Power Engineering: A practical manual on the concentration and transmission of power by hydraulic machinery. By G. Croydon Marks. London: Crosby Lockwood & Son. New York: D. Van Nostrand Company. 1900. 8vo, pp. 360. (Price, $3.50.)

The present work is intended by the author as an aid to engineers engaged in the designing and construction of works and machinery for the utilization of water for power transmission. The author disclaims the idea that his work deals adequately with all the problems arising in the practice of hydraulic engineering, but he has made a satisfactory attempt to present in intelligible form a description and discussion of the essential features of the subject as they will be called into requisition by the needs of the hydraulic engineer. W.

Leçons d'Électrotechnique Generale, professées a l'École Superieure d'Électricité. Par P. Janet, Directeur du Laboratoire Central et de l'École Superieure d'Électricité. (Large 8vo, pp. ix-608, with 307 figures.) Paris: Librarie Gauthier-Villars. 1900. (Price, 20 francs.)

This volume may be considered as a supplement to the same author's *Premiers principes de l'Électricité industrielle*, previously noticed in the *Journal*. It is an elaboration of the course of instruction in electrotechnics followed in the École Superieure d'Électricité in Paris. W.

Hand-book of Practical Hygiene. By D. H. Bergey, A.M., M.D., First Assistant, Laboratory of Hygiene, University of Pennsylvania, Philadelphia, Pa. Easton, Pa.: The Chemical Publishing Company. 1899. 8vo, pp. 164. (Price, $1.50.)

This work has been prepared with the view of affording the student a convenient hand-book to serve as a guide in practical laboratory work in the sanitary examination of air, water, soils, the principal food products, and in testing the ventilation of buildings. The five chapter heads treat of the subjects above named and in the order given.

The analytical methods given are generally the more simple and convenient ones, and the instructions given are clear and concise. The book should prove extremely useful as a laboratory guide. W.

The Chemistry of Soils and Fertilizers. By Harry Snyder, B.S., Professor of Agricultural Chemistry, University of Minnesota. Easton, Pa.: The Chemical Publishing Company. 1899. 12mo, pp. ix-277. (Price, $1.50.)

This is an elaboration in book form of the course of instruction given by the author to the classes of young men attending the University of Minnesota, who intend to become farmers, and who need some knowledge of the chemical and physical properties of soils, of the nature of plant growth and nourishment, the exhaustion of soils, the conservation of soil fertility by the proper selection and use of fertilizers, etc., etc.

These subjects are all treated of in this hand-book in a plain, comprehensible way. Practical agriculturists generally should find it helpful.

W.

Commercial Organic Analysis. By Alfred H. Allen, F.I.C., F.C.S. Third Edition, with Revisions and Addenda by the Author and Henry Leffmann, M.A., M.D. Vol. I and Vol. II. Philadelphia: P. Blakiston's Son & Co. 1898.

This revised and augmented edition of Allen's unique work is certain to meet with a hearty reception by the analytical fraternity. It is several years since the second edition of the work has been exhausted, but no other book as comprehensive in scope and accurate in detail has yet appeared to take its place. A mere reprint even would have been welcomed by many chemists. While this first volume of the new edition has not, perhaps, been revised as thoroughly as it might have been had the American editor been given a freer hand and ampler time, it must be conceded that the joint endeavors of the

author and editor have gone very far towards bringing the work up to date. The first volume is now devoted to the general analytical operations, the alcohols and their neutral derivatives, the sugars, starches and vegetable acids. On the whole, these subjects are treated very satisfactorily many of the additions made by Dr. Leffmann being of special interest to American chemists.

The author and Dr. Leffmann have also collaborated in the preparation of the second volume, of which the second part has just been issued. Its revision appears more thorough and complete than that of Vol. I; the American editor has added largely to the sections on hydrocarbons, petroleum and coal-tar products, and asphalt—the last-named subject being treated in a masterly manner—while Mr. Allen has given special attention to the description of the tests of phenols and allied subjects. The new classification of the hydrocarbons, the addition of certain technological summaries, such as those on acetylene and coke-oven tars, and of tables of comparison of density and temperature scales are worthy of special mention. H. F. K.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, June 20, 1900.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 20, 1900.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 135 members and visitors.

Additions to membership since last report, 23.

Mr. Arthur M. Greene, Jr., Dr. Joseph W. Richards and Mr. Henrik V. Loss were authorized to act as delegates of the Institute to the various scientific congresses to be held in connection with the Paris Exposition.

The President announced that arrangements had been made for the reception of the reports of various members of the Institute who had made observations of the recent solar eclipse (of May 28th).

Dr. A. E. Kennelly, Mr. H. M. Watts, Dr. Chas. F. Himes, Mr. F. E. Ives, and others, thereupon presented accounts of their respective observations. (The full account of the remarks of these observers appears elsewhere in this impression of the *Journal.*)

Dr. Wm. H. Greene, who was announced on the program for a paper on "Prismatic Lighting for the Illumination of Dark Interiors," being prevented from attending the meeting, his paper was read by Mr. Chas. C. Hicks. The paper was freely discussed, and the subject was referred to the Committee on Science and the Arts for investigation and report.

The Secretary exhibited commercial specimens of sheet steel architectural work, casted with pure lead, by the process operated by the Ajax Metal Company, of Philadelphia.

Adjourned. WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, June 6, 1900.*]

MR. H. R. HEYL in the chair.

The following reports were adopted:

Machine for Tangible Writing for Touch Reading.—W. B. Wait, New York.

ABSTRACT.—The applicant submitted two machines, the object of which is to produce embossed writing by means of which the blind are enabled to write and read.

The method of Mr. Wait is a modification of the system first devised by Braille, and known by his name, in which the signs or letters consist of one or more raised points, the relative location and configuration of which determine the character.

In the Wait system, known also as the New York point system, each sign occupies the space of either one, two, three or four vertical rows of two points each. In this, as in the Braille system, the letters are separated by spaces somewhat exceeding the distance between the vertical rows in each sign, and words are divided by a still greater space.

Two machines were submitted by the inventor; one, the smaller of the two, adapted to make the impressions directly upon paper, and operated by hand; and the other, operated by foot-power, intended for producing the plates used in the process of reproducing the embossed sheets used by the blind. This machine is strong enough to make the impressions on thin sheets of brass, which are subsequently used to make similar impressions on sheets of paper. (The details of construction cannot be made intelligible without illustrations.)

The conclusion reached by the investigators is as follows: "As compared with similar machines made for producing the embossed writing of the Braille system, * * * the machines of applicant are superior, both in details of mechanical construction and in workmanship, to those previously made." The report further specially commends the ingenuity with which the "variable feeding" has been accomplished. The committee recommends the award of the John Scott Legacy Premium and Medal. [*Sub-Committee.*—Hugo Bilgram, Chairman; Edward E. Allen, B. N. Lehman, F. E. Ives, Louis E. Levy.]

System of Incandescent Lighting.—Welsbach Light Co., Philadelphia. (Referred by the Bureau of Awards, National Export Exposition.)

ABSTRACT.—This report embraces a historical sketch of the art of incandescent lighting by gas and electricity, and is reserved for publication in full. The award of the Elliott Cresson Medal is made to Dr. Carl Auer von Welsbach for his discoveries regarding the metallic oxides which may become incandescent when heated and for the invention of a mantle by the use of which these metallic oxides are commercially available as sources of artificial light.

The Edward Longstreth Medal of Merit is also awarded to the Welsbach Light Company for the successful industrial development of these discoveries [*Sub-Committee.*—Arthur J. Rowland, Chairman; Chas. A. Hexamer, Wm. McDevitt, Moses G. Wilder, Frank P. Brown.]

Improvements in Carriages and Wagons.—Chas. S. Caffrey Co., Camden, N. J. (Referred by the Bureau of Awards of the National Export Exposition.)

ABSTRACT.—This report relates to the exhibit of carriages and wagons made by the manufacturers at the National Export Exposition, and grants to them the award of the Edward Longstreth Medal of Merit for excellence in design and workmanship and for lightness and novelty exhibited in their products. [*Sub-Committee.*—Arthur M. Greene, Jr., Chairman; Chas. R. Torkington, Caspar Kendall.]

Universal Ratchet.—Waterbury Tool Company, Waterbury, Conn.

ABSTRACT.—This invention is the subject of letters-patent of the United States (No. 613,950, November 8, 1898), granted to H. D. Williams, H. G. Hoadley and E. C. Lewis. It consists of a substantial ratchet-box, with diagonal trunnions to which the operating lever is attached.

The object of the improvement is to produce the rotary movement of a shaft by means of the vibratory movement of a lever, which vibration may be in various planes, as well as in a plane at right angles to the shaft. The tool is, therefore, adapted to operate successfully in difficult situations where obstructions might make the use of an ordinary ratchet impossible, while at the same time provision is made for its operation in the usual way. For details of the mechanism, reference is made to the above-named patent specification.

The investigators find that the construction of the tool is in every respect good and substantial; that attention has been paid to the requirements for a serviceable and convenient ratchet; and that, when the facilities which it offers for meeting trying situations are considered, the space which it occupies is surprisingly small. All the working parts are case-hardened, and every detail testifies to the care taken in its design and construction as a part of a clever and ingenious whole. The inventors are awarded the Edward Longstreth Medal of Merit. [*Sub-Committee.*—Wilfred Lewis, Chairman; Henry F. Colvin, Spencer Fullerton, Luther L. Cheney, Thos. P. Conard.]

Variable-Speed Countershaft.—Milton O. Reeves, Columbus, Ind.

ABSTRACT.—The invention is a device designed to give to a machine any intermediate speed between two limiting values, and to accomplish this while the apparatus is in motion.

For details of construction and operation, reference is made to United States letters patent Nos. 581,770, 583,402, 584,402, 507,403, 588,354, 603,067, 606,941, issued to said Reeves; and in part to E. K. Hood. The dates are between May 4, 1897–July 5, 1898.

The report embodies a description of the mechanical operation of the device and a comparison with other devices used for the same purpose.

The conclusions are: (1) that the motion transmitted by the device is practically uniform at all positions; (2) that the belt tension can be kept practically constant; (3) that the apparatus can be changed while in motion to any speed within the limits; (4) that the power transmitted is limited by the excessive weight of the belt, which increases the centrifugal tension with-

out affording any corresponding increase in strength ; (5) that the apparatus may be adapted to any machine requiring an adjustable speed, as automobiles, lathes, boring mills, etc.; (6) that the efficiency is fairly high ; (7) that the apparatus wears well.

The award of the Edward Longstreth Medal of Merit is made to the inventor. [*Sub-Committee.*—Wilfred Lewis, Chairman; Arthur M. Greene, Jr., Luther I. Cheney.]

Obtaining Energy to Run Automobiles.—John Stolze, Reading, Pa.

ABSTRACT.—The applicant proposes to couple an air compressor to the running-gear of a compressed-air driven automobile vehicle in such manner as to admit of the compressor being actuated by the vehicle itself while on down grades. The air so compressed is to be added to the initial supply, stored in a suitable chamber, thus increasing the performance of the vehicle for a given initial supply of compressed air.

The investigators express the opinion that the advantage to be derived from such a combination is not great enough to give to the invention a commercial value. [*Sub-Committee.*—Geo. S. Cullen, Chas. C. Heyl.]

Double-reciprocating Square Piston Engine for Steam and Compressed Air.—W. F. Dake, Grand Rapids, Mich.

ABSTRACT.—This invention is the subject of letters-patent of the United States, issued to applicant (No. 359 039, December 25, 1888).

The engine is provided with a suitable casing having a chamber in which is held, so as to be able to move backward and forward horizontally, a rectangular piston having a chamber in which is mounted to slide vertically the inner piston, which is carried on a wrist-pin secured to a crank-disc on the main driving shaft. On top of the casing is a steam-chest with a 4-way valve controlled by a handle. Into this valve leads the steam pipe, and out of it the exhaust pipe. The engine can be run in either direction by changing the position of the said valve. The necessary ports and channel-way are provided in valve box and casings, and provision is made to prevent leakage by packing-strips, set-screws, etc.

The investigators find this form of engine very compact, permitting it to be used where engines of the usual types would be excluded on account of space. The Dake engine, however, requires fine adjustment when made and will soon begin leaking if not well balanced. It shakes badly at high speed, and uses more steam than many others doing the same work. This type of machine is suitable only where the work is intermittent, and even in these cases is not altogether satisfactory. [*Sub-Committee.*—L. F. Rondinella, Chairman ; J. M. Emanuel, Henry F. Colvin.]

The following reports passed first reading :

Artificial Production of Graphite.—E. G. Acheson, Niagara Falls, N. Y.

Hydraulic Air Compressor.—Continental Compressed Air and Power Company, Philadelphia. (Referred by the Bureau of Awards of the National Export Exposition.)

Incandescent Lamp.—International Incandescent Light Company, Philadelphia. (Referred by the Bureau of Awards of the National Export Exposition.)

These reports were held over under advisement until the next meeting.

W.